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VOL. XX, NO. 5 MAY, 1925

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK, N. Y., Grand Central Terminal

Single Number 50 cents Yearly Subscription $5.00

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THE SCIENTIFIC MONTHLY

MAY, 1925

ANCIENT CLIMATES[1]

SOME FACTORS OF CLIMATIC CONTROL

By Dr. W. J. HUMPHREYS

U. S. WEATHER BUREAU

Introduction

A knowledge of how climates are controlled and through what agencies they have been changed from one condition to another is an end within itself devoutly to be desired. Furthermore, it would be the means to other ends. It would enable us to infer from a known climatic condition the state of the factors that produced that condition; when we know the causes of effects, from effects we can infer causes. Let us see then how, in the main, climate is regulated to-day and to what extent its determinants are variable, for unquestionably its controls in the past were precisely the same as those of the present and only those now variable were then variable.

Cosmical Controls

Output of solar energy: As is well known, all the heat, or radiant energy converted into heat, that comes to the earth from the moon, the planets, the thousands of nebulae and the millions of stars is climatically entirely negligible in comparison to that which comes from the sun. If, then, the climatic changes of the past were largely caused by variations in the amount of radiation coming to the earth these variations in turn must have been owing to corresponding changes in our distance from the sun (considered below) or in its intrinsic radiational intensity; that is, its rate of emission per unit area.

Now, geological evidence shows that extensive mountain building always, so far as we can judge, was followed by a period of

[1] Papers presented at a symposium on "Ancient climates" held in connection with the meeting of Section E, American Association for the Advancement of Science, Washington, D. C., January 2, 1925.

cooler to colder climates. Hence to insist that the major climatic changes of the past were induced by corresponding solar changes is to urge either that the towering of the mountains was caused by the paling of the sun, or the paling of the sun by the towering of the mountains, or, finally, to assume for crustal folding and solar failure some mysterious common cause. If this logical deduction is untenable, as it seems to be, then however much or little the activity of the sun may have varied in the past that variation alone can not have been the sole cause, nor even the chief cause, of all the numerous climatic changes indelibly recorded in the book of ages.

Solar distance: Since the intensity of heat received from a point source varies inversely as the square of the distance from that source, we have only to postulate suitable variations in our distance from the sun to account for any local climatic change whatever. No more enticingly simple explanation than this can possibly be found, but, however adequate it appears, the unyielding laws of celestial mechanics strictly forbid its adoption. True, the orbit of the earth about the sun does vary in shape owing to changes in the magnitude and direction of the resultant attraction between our planet and the rest of the solar system. Furthermore, these gravitational changes so rotate the orbit itself and axis of the earth that first one hemisphere and then the other, in a complete period of about 21,000 years, has its winters when we are farthest from our source of heat, and when therefore they are longest (the farther from the sun the slower we move) and coldest. Hence, it is argued, when the orbit of the earth is quite eccentric—departs widely from a circle—that hemisphere that is having its winters when most distant from the sun, aphelion winters, will rapidly accumulate ice and snow and thereby enter upon an age of glaciation.

It must be granted, of course, that the eccentricity of the earth's orbit does change and that this change does affect our climates. On the other hand, according to the rigid computations of the astronomer, this eccentricity has been nearly constant and quite small for fully 80,000 years—way back into the last ice age, and not just since its virtual close. Besides, there is no evidence, apparently, that glaciation occurred alternately in the northern and the southern hemispheres. Finally, no indication has been found that within the last 3,000,000 years, during most of which time the eccentricity of the earth's orbit has been comparatively large, there have been, as this theory would require, 100 or more extensive glacial advances and retreats in each of these regions. Variations, then, in the earth's orbit, though slightly altering our temperatures, presumably had but little part in bringing about the climatic

changes of the past. Indeed, so far as we know, they may as often have ameliorated as intensified these changes.

Obliquity of the ecliptic: Since the direction of the earth's axis in space changes but slowly, its conical motion having a period of about 26,000 years and its inclination to the plane of the ecliptic (plane of the earth's orbit) being practically constant through the ages, it follows that every year a series of seasons must succeed each other, as the sun passes from side to side of the equator, with temperature extremes, at least, roughly proportional to the inclination of this axis to the plane in question, that is, the ecliptic. If, then, we could play fast and loose with this inclination we easily might account thereby for any number of climatic changes of certain kinds. But here again that safest of all mentors, Mathesis, informs us that in accordance with the laws of celestial mechanics this inclination can never vary more than a degree or two on either side of the mean, and that with a period of a million years or more. Important climatic changes therefore can not be attributed to corresponding changes in the obliquity of the ecliptic—for these did not occur.

Perihelion phase: Since the earth passes the perihelion and aphelion of its orbit, or points closest to and farthest from the sun, respectively, about 2.5 minutes later from year to year, it follows that first the southern hemisphere, as is now the case, and then, in about 10,000 years, the northern, has relatively long cold winters and short hot summers. And as the longest winters exceed the shortest by about 4 per cent., while the total amount of heat received by the earth is the same for all half years (time of apparent passage of the sun from the one to the other of any two opposite points on the ecliptic) whatever their periods, it might seem, from the fourth power law of radiation, that the absolute temperatures of the two winter extremes should differ by approximately one per cent., or, say, 2.8° C. However, owing to the reservoir, or flywheel, action of the earth, the oceans especially, in storing up and giving out heat, no such temperature contrasts can occur. The longer winters begin a little milder than the short ones and end a little colder, but not enough warmer in autumn or colder in spring, and will not, so long as the eccentricity of the earth's orbit has its present small value, be of any appreciable climatic importance.

Sunspots: For some reason or reasons entirely unknown, spots of greatly decreased luminosity form on the sun in numbers that pass through an average cycle of a little over eleven years. These changes in the state of the source of our heat are accompanied, as we should suspect, by variations in the average temperature of the

earth. However, the range of these variations is small, roughly 1° C., hence, and also because the period of the cycle is short, of little interest in respect to climatic changes.

One might insist of course that the existence of small changes in the sun of short period indicates that the climatic variations of the past were caused by large solar changes of long period. This would be an easy solution of a difficult problem if we could find any adequate cause of the requisite changes of the sun. But as no such cause is even suspected we must continue at present to hunt for the sources of climatic changes in those factors of climatic control that are known themselves to have varied.

Passing through nebulae: It has been suggested that each glaciation of the past may have been owing to the enfeeblement of sunshine incident to the passage of the solar system through a nebula. Conceivably so, but if the luminous nebulae are as far away as the fixed stars, as they seem to be—many indeed vastly farther—then the Quaternary ice age, at least, could not have been thus caused, for we would not have become separated so far from the screening nebula in so short a time. But not all nebulae are luminous. Many are dark and of them we have practically no knowledge. If, however, they are islands of dead cosmic dust, in places of equilibrium under variously directed light pressures, then surely it never was one of them through which we passed—we never could have caught up with it in its flight on the approach of the sun.

Finally, the enfeebling of insolation in this manner would produce only a *lowering* of temperature, whereas we are confronted not only with the problem of accounting for much lower temperatures over various periods of the past than now prevail, but also with the equally difficult problem of accounting for much higher temperatures over vastly longer periods. Apparently, then, the nebulae offer but little help in the solution of our climatic problem. Warmer climates certainly were not produced by them, and it seems hardly possible that any of the colder were so caused.

Terrestrial Controls

Earth heat: The total flow of heat from within the earth amounts to only about 60 calories per year per square centimeter of surface, the equivalent, roughly, of one hour's sunshine. If this supply were cut off entirely, or, on the other hand, doubled, in either case the resulting climatic effect would be negligible. Furthermore, so far as we can judge from our knowledge of the sources of this heat (residual internal heat and radioactivity) its rate of delivery to the surface must have been very small for too long a time to permit the assumption that it was an important factor in the control of any recorded climate.

The idea that the warmer climates of the past were caused by the greater supply then of residual earth heat is, of course, hard to give up, but the laws of physics and the logic of numbers seem very positive that, however reluctantly, it must be abandoned.

Latitude: It has been urged that all the greater climatic changes, and many also of the minor ones, of any given place, have been caused by its change of latitude. Some have suggested that the earth as a whole retained the inclination of its axis to the ecliptic and despite that so turned from time to time as either spasmodically or gradually greatly to shift the positions of the poles. This simple way of explaining climatic changes however is strictly forbidden by celestial mechanics.

Others have argued that islands and even continents are but fragile cakes of frozen stone floating hither and yon on a sea of molten rock, thereby changing their latitudes and climates. This bold hypothesis has more than once commanded some attention, but seems now to be practically abandoned—wrecked alike by logic and observational evidence.

Another conceivable way of shifting latitudes would be to skew about the relatively thin outer shell of the earth over the plastic interior, leaving the axis of rotation but little changed. But we are not sure the interior is mobile to the degree this would require, nor, if it were, is there any known force capable of producing such a turning of the shell.

Clearly, then, the hypothesis that the known climatic changes have been caused by corresponding shifts of latitude is not tenable.

Land elevation: Although both logic and observation forbid the assumption that any portion of the surface of the earth may shift its position horizontally to a materially different climatic zone, exactly the reverse is true in respect to the vertical. We know that the height of the land, and especially the mountainous regions, above sea level has varied greatly through the ages. This has been owing in part to the transfer of water from the oceans and its accumulation in the form of ice on the islands and continents. Thus, if all the ice now so accumulated were melted every ocean would be raised by about 40 feet. The chief causes, however, of the rise and fall of plateaus and mountains are matters concerning which facts are still fewer than hypotheses. But they do rise and they do fall, and that is sufficient for our present purpose.

In the case of mountains the decrease of temperature with height is about 1° C. per 180 meters, hence in middle and higher latitudes many peaks even now rise well above the snow line. Obviously, too, when a high ridge lies for a great distance across the path of the prevailing winds (and many such ridges have existed as some now

exist) a relatively large amount of precipitation occurs on its windward slopes, while the lee side for hundreds of miles is more or less arid. Also, if the temperature is low enough, much snow falls to the lee of the crest and much more is blown over, so much indeed as, under favorable circumstances, to build a leeward progressing drift even higher than the ridge of rock that started it. Hence a mountain, if properly situated, and if the land beyond also is high, might lead to the filling of valleys with ice and the formation of a great glacier plateau.

Owing to their free and abundant radiation, all the more pronounced when snow covered, mountain crests and peaks also are colder than the free atmosphere at the same level. Consequently a vast amount of cooled air drains down their sides and adds its chill to the valleys and plains beyond. Clearly, then, high mountains and elevated plateaus make for bitter cold and abundant snow. On the other hand, the lowland climate is relatively mild for its latitude, and, in general, all the more so when unaffected by neighboring mountains. Land elevation, therefore, is a climatic control of very great importance, and one that has abundantly varied throughout geologic time; but it is not the only one.

Land and water distribution: As is well known, land intensifies and water moderates temperature extremes. Much of the heat absorbed by water merely produces evaporation. However, there also is considerable evaporation from the land, hence the summer contrast between the temperature of land and water is not as great as it would be if the land were absolutely dry. During winter, cooled surface water sinks and is replaced by warmer water from beneath as long as the supply lasts—all winter if the water is deep. No such convection, however, can occur on land. The surface of cooling land can not sink, as can water, beneath warmer layers below, but must stay at the top and merely get colder. The contrast, therefore, between land and water temperatures is greatest during winter. Hence also winter temperatures are more lowered than summer temperatures are raised, by land in the prevailingly windward direction. The eastern shore of Lake Michigan for instance has a far more equable climate, a climate well adapted to the growing of peaches even, than the western, and all because the prevailing winds cross the lake from west to east. Similarly, the winters of the Ohio Valley, dominated by northwest winds that have come long distances overland, are far colder now than they would be if the ocean covered, as of old it did, the whole continental valley from the Gulf of Mexico to the Arctic Sea. Numerous other similar examples could be cited in support of the thesis that the distribution of land and water is an important climatic control, but the fact is too well known to require further evidence.

Oceanic circulation: There are two great causes of oceanic circulation, namely, the drag of the winds and difference of density incident to variations in salinity and temperature. The first of these appears to be by far the more important of the two, at least in the movement of the surface water, the only portion that affects the state and condition of the atmosphere, or, in short, affects our climates. The great currents and drifts of oceanic water such as the Gulf Stream, the Japanese Current, the Labrador Current, the Humboldt Current and many others, moderate the heat of the tropics and wonderfully temper the cold of high latitudes. Oceanic circulation, therefore, is one of the most effective of all the controls of climate. Furthermore, it clearly has undergone many and profound changes incident to variations in the distribution of land and sea. If, for instance, the Gulf Stream could flow directly into the Pacific Ocean obviously the Scandinavian peninsula and at least the Highlands of Scotland would become glaciated. The great cyclonic center of action near Iceland would not exist. The belt of most rapid fall of temperature with increase of latitude, hence the belt of strongest winds and most frequent cyclones, would be much farther south over Europe. Storms would follow the Mediterranean far more frequently than they now do. Northern Africa would again become a wooded and watered region. Palestine and places beyond would rejoice in a greatly increased rainfall, but all at fearful cost to Europe.

On the other hand, if both the Gulf Stream and the Japanese Current had free and wide access to the Arctic Ocean the temperatures of that region certainly would be distinctly higher. There then would be fewer and milder outbreaks of cold air from the Arctic regions, fewer storms and gentler winds over the northern hemisphere and a host of other differences in the climate from that which now prevails. All that is necessary to work such profound climatic changes is the appropriate distribution of land and sea and the consequent regulation of the hot water heating system of the earth.

It has been argued that these apparently obvious conclusions are sadly in error, that even if the ocean covered the entire face of the earth the polar regions still would remain hopelessly frigid, and proof has been offered in the horrible climate of Kerguelen Island at 49° 40′ south latitude in the very midst of the Indian Ocean. The present climate of this island, however, is determined by conditions widely different from those assumed to give relatively mild polar temperatures. Antarctica, because of its considerable height and great extent, is shedding vast streams of frigid air onto the surrounding oceans, and continuously chilling them

with countless millions of tons of ice, both fixed and floating. Naturally, then, the surface of all the circum-Antarctic drift, the air above it, and the climate of every speck of land in its path, including of course Kerguelen, are cold and disagreeable. If, however, Antarctica did not exist there would be none of its drainage blizzards nor any of its vast fields of ice to chill the surface waters. Surely the temperature of the air would then be much higher, winds gentler and storms less frequent.

Salinity of the oceans: One of the most pleasing hypotheses ever offered in explanation of the mild temperatures of high latitudes is that based on the salinity of the ocean. If the increase of density owing to increase of salinity, incident to evaporation, in warmer latitudes should exceed the increase of density in high latitudes caused by low temperature, then this concentrated brine would flow as a warm and protected subsurface current to the colder regions, there rise to the surface, especially if the sea in those places were diluted by abundant precipitation or drainage, and give over much of its imported heat to the adjacent air. Such a circulation of the oceanic waters obviously would be of very great climatic importance.

That such a circulation might occur is partly indicated by the great sags in the isothermal surfaces as they cross the high pressure belts of the ocean, roughly centered along latitudes 30° north and south, respectively, where evaporation is much in excess of precipitation. The warmest deep water therefore is not along the equatorial belt, but along those belts, still in warm parts of the earth, where surface salinity is above normal.

However, not all the sinking of ocean water under the high pressure belts is attributable to increase of salinity. These belts, or sections, rather, of belts, are encircled by prevailing winds which, through the rotation of the earth, cause water to pile up within the encircled area, where of course it must sink.

Finally, the great bulk of ocean circulation, save the very deep and sluggish portions, is actuated by the wind, however much modified by the rotation of the earth, and deflected by continental and other barriers. These wind-driven currents also keep down to a minimum contrasts of salinity. Hence, while the so-called reverse ocean circulation may possibly have obtained at times, there is lacking both the conclusive evidence that it ever did, and rigorous proof that it actually could have.

Surface covering: The nature of the covering of land surfaces (the ocean surfaces are excluded because always essentially the same) whether, for instance, succulent vegetation, bare soil, including sand and rock, or snow, is of great climatological importance. Most soils and rocks are good absorbers of solar energy,

but poor emitters of earth (long wave length) radiation. On the other hand, snow absorbs solar energy, the greater portion of which lies in or close to the visible region, very imperfectly, as is obvious from its brilliant white glare in sunshine, and emits earth radiation twice as well, roughly, as bare soil or rock. Clearly, then, an extensive covering of snow, because it reflects so great a portion of sunlight, affects the region concerned much as would a very considerable reduction in the solar constant, for reflected radiation had as well never existed so far as heating the reflector is concerned. In addition to this the snow covering, because of its comparative excellence as a low temperature radiator and its exceedingly small thermal conductivity will cool to still more frigid temperatures. Hence, as already stated, surface covering, at least as between soil and snow, if of wide extent, is an important climatic control.

Atmospheric circulation: Since the cold winds of polar regions flow equatorward, however devious the paths followed, and the warm tropical winds poleward, it is evident that atmospheric circulation tends greatly to equalize the temperatures of the globe. Furthermore, owing to this circulation the greater portion of evaporation, a cooling process, occurs in the warmer regions, and a large portion of the condensation, a process that liberates much heat, in the cooler regions.

Also, as explained above, it is the winds, mainly, that drive the ocean currents. Hence, atmospheric circulation also is an exceedingly important climatic control, however much it in turn depends on other things, such as zonal contrast in temperature, positions and heights of mountains and distribution of land and water.

Extent and composition of the atmosphere: Since the atmosphere absorbs solar radiation to some extent and earth radiation in a much larger measure it obviously protects our land areas from becoming scorched by day and frozen at night. Clearly, too, this action would vary with the amount of the atmosphere, other things being equal, above the places concerned. But we do not know to what extent the total quantity of the atmosphere has varied, though of course we do know that the amount above given areas varied with their elevation above sea level. This virtual variation of our thermally protective cover is one of the indirect effects of changes in elevation.

Only a small portion of the atmosphere, really less than one per cent. of the whole, is at all effective as a thermal covering. Water vapor, chiefly, carbon dioxide slightly, and ozone, also slightly, are the only portions of the atmosphere that absorb appreciable amounts of either solar or terrestrial radiation. All three

of these constituents are variable, the water vapor most of all and rapidly so in response especially to temperature. A cool earth would have a thin vapor blanket, a warm earth a thick one. The amount of carbon dioxide has varied very slowly and over long periods in response to vulcanism, and the relative rates of hoarding and releasing carbon and carbonates.

It happens, however, that in its relation to radiation carbon dioxide is but little different from water vapor, so that as long as there is far more water vapor in the atmosphere than carbon dioxide, variations of the latter are of minor importance.

The changes in amount of ozone, a constituent of only the high atmosphere, are not known, but depend, apparently, more on the state of the sun than on the condition of the earth beneath.

Seemingly, then, the variations of water vapor in the atmosphere, incident to temperature changes, positions and heights of mountain ranges, and distribution of land and sea, have produced far greater climatic effects than have the changes in carbon dioxide or any other atmospheric constituent.

Volcanic dust: That portion of volcanic dust that floats for months or years, as sometimes happens, in the high atmosphere beyond the reach of clouds, is both coarse enough to shut out much of the incoming solar radiation and yet too fine to keep in much of the outgoing earth radiation. It, therefore, produces an inverse greenhouse effect, and necessarily leads always to lower terrestrial temperatures than otherwise would have prevailed. Hence the extent to which volcanic dust has been a climatic control has varied according to the amount of such material spread from time to time through the upper atmosphere, the frequency of such occasions, for this dust drops out in the course of one to three years, and the condition of the earth, especially with respect to land extent and elevation at the time of explosive activity. This last condition, though very important, seems usually to be overlooked.

Conclusion

Of the many factors of climatic control, all those of extra-terrestrial or cosmical origin either are demonstrably small or unproved, and, apparently, unnecessary to assume in accounting for the known climatic changes of the past.

These changes have been many and some have been profound, and all, we believe, were produced essentially by the earth itself. We hold this thesis because with ever so constant an output of solar energy and uniformity of other astronomical elements certain alterations of topography and other terrestrial conditions, no greater than those known to have occurred, surely would profoundly affect the present climates of the world.

The warmer periods (for middle and higher latitudes especially) were, it is believed, at those times when the land areas were relatively restricted and of small elevation and oceanic circulation free and open to high latitudes. The colder periods, including the ice ages, were, presumably, at the times when land was extensive, mountains abnormally high, and oceanic circulation restricted, especially in the more frigid zones. At such times the climates would be at least relatively cool while the loftiest peaks and ranges outside the tropics would carry many a glacier of greater or less magnitude. Under these conditions our climates would be in a critical state. A few violent volcanic explosions, for example of the Asama and Krakatoa type, say one a year for a dozen years, might well be disastrous. Every thick veil of volcanic dust, such as here contemplated, and as occasionally has been formed within historic times, necessarily and appreciably lowers the average temperatures. This in turn, if, as assumed, land is unusually extensive in middle and higher latitude regions, would lead to a greatly extended snow covering during every season of the year. Such a covering, in addition to itself cooling, by virtue of being a good radiator, to still lower temperatures would return to space untrapped and unused a large percentage of the incident solar radiation—a virtual decrease in the solar constant. Finally, this cooling would be further intensified by the incident thinning of our protecting blanket of water vapor. More upper air charges of volcanic dust, no matter where originated, would of course still further lower our temperatures, whatever they might happen to be, but they would not be essential to the disaster already begun—one does not have to keep on pulling the trigger after firing a gun.

In short, the earth has, we hold, produced its own climatic changes through such potent agencies as land and water distribution, land elevation, oceanic circulation, atmospheric circulation, volcanic dust and surface covering, and will, we believe, by these means yet produce many another such change.

EVIDENCE OF INVERTEBRATES ON THE QUESTION OF CLIMATIC ZONES DURING MESOZOIC TIME

By Dr. TIMOTHY W. STANTON

It should be stated at the outset that I am presenting a question rather than a thesis, the question being whether there were climatic zones during the Mesozoic era. The evidence to be considered relates chiefly to differences in Mesozoic marine invertebrate faunas

which may possibly be attributed to differences in temperature of the waters in which they lived.

No one will question that the present fauna of the cold Arctic seas differs greatly from the fauna of tropical waters, and that a fauna of intermediate character inhabits the temperate waters between the two extremes. This is of course particularly true of littoral and shallow-water faunas which are subjected to zonal differences in climate with temperature range in surface waters from a little below freezing (−1.7° C., 29° F.) to summer heat (27.4° C., 81° F.). In depths below 1,000 meters the temperature is relatively uniform at a few degrees above freezing (3° C., 37° or 38° F.) and the faunas also show much less differentiation. A similar zonal distribution of faunas is recognized in the southern hemisphere. The geographical limits of these zonal faunas are not sharp lines and they by no means coincide with parallels of latitude. They are shifted long distances one way or the other by the influence of ocean currents, and many other elements such as the nature of the bottom, the amount and character of sediments received, the presence or absence of barriers of various kinds, food supply and many other things enter in to determine the boundaries of more local faunal provinces.

Among all the varying factors just suggested it is not difficult to recognize the influence of temperature on living faunas. Reef-building corals, for example, do not live where the temperature of the water goes below 68° F., and some of the more important groups of these corals live in still warmer waters with a minimum temperature of 74° F. The molluscan fauna of tropical waters shows its exuberance by a much greater number of species and genera as well as of individuals than are found in the boreal seas. Each zonal fauna has many characteristic genera which are either restricted to it or best developed and most common in it.

It is universally accepted that there are faunal realms and provinces in the modern seas and that a part of this differentiation is directly due to climate. The invertebrate faunas of the other geologic periods are also distributed in faunal realms and more local provinces. According to Ulrich this is true from the beginning of the paleontologic record. Ulrich[1] says: "Except in a very broad generic way, I question if there ever was such a thing as a cosmopolitan littoral or shallow-water bottom fauna. Some of these faunas doubtless attained great distribution in certain geologic times, but aside from a few highly adaptable species and genera, they have always been limited by barriers of some kind to smaller or larger areas beyond which they could not spread." In another

[1] Ulrich, E. O., "Revision of the Paleozoic systems," Geol. Soc. Am. Bull., Vol. 22, p. 366, 1911.

passage in the same work,[2] Ulrich states that "comparative studies of Paleozoic faunas in the northern hemisphere suggest grouping them into three major faunal realms; namely, (1) an Atlantic, (2) an Arctic and (3) a Pacific," which he divides into a number of local provinces. This classification which may be interpreted as an Arctic or boreal realm set off from the rest of the world sounds like the beginning of a zonal arrangement due to climatal differences, but it is not so interpreted. Ulrich himself says in another place,[3] "taking the geological marine record, as preserved in the rocks from the Cambrian to the Tertiary, it suggests equable, mild, almost subtropical climate over the whole northern hemisphere in all the ages represented." He does, however, accept the evidence of local glaciation in certain epochs and suggests that the deposition of a certain type of black shale may be due to a cool climate.

Schuchert[4] interprets the record as indicating an alternation of mild with cool or even cold climates, stating that when "during the geologic ages the lands were reduced to but little above sea level . . . there were world-wide mild climates."

The marine invertebrate faunas of the Mesozoic were certainly more or less localized, though some of them extended over wide areas. This was true to some extent even of the Triassic, which is generally believed to have had a world-wide mild climate, as indicated, for example, in the Lower Triassic when the same kind of a cephalopod fauna lived in India, in northern Siberia and in the western part of the United States. The differentiation into local faunas was still more marked in later Jurassic and in Cretaceous time. It was in the study of the distribution of these faunas, especially of the ammonites in them, that Neumayr[5] recognized a zonal distribution which he attributed to climatal differences. His zones were boreal, middle European and Mediterranean, each characterized by particular genera of ammonites, or the absence of them, and corresponding in a general way with the frigid, north temperate and tropical zones of the present day.

Since Neumayr's time much has been learned about the distribution of Jurassic and Cretaceous faunas in all parts of the world, and in consequence Neumayr's conclusions and some of the data on which they were based have been questioned by several geologists, notably Burckhardt,[6] who has stated that he has seen genera of ammonites supposed to be characteristic of each of Neumayr's

[2] *Op cit.*, p. 483.

[3] *Op. cit.*, p. 352.

[4] Schuchert, Charles, "Text-book of Geology," 2d ed., p. 447.

[5] Neumayr, M., "Klimatische Zonen während Jura und Kreidezeit," 1883.

[6] Burckhardt, Carlos, Soc. Cient. Antonio Alzate, Mem. 31, pp. 107–115, 32, pp. 79–84, 1911, 1912.

zones all associated in one bed in Mexico and even as far south as the Argentine cordillera. He also calls attention to the abundant occurrence in Mexico of the boreal pelecypod Aucella, which is so widely distributed in all the northern circumpolar region and along the Pacific coast from Alaska to Southern California. Perhaps if Aucella had been first discovered and described in Mexico instead of in Russia we would now be speaking of the great northern extension of a tropical genus. There is always the tendency to regard the place where a species or a genus is first found as its original home, but in this case there can be little doubt that Aucella is really a boreal form and boreal faunas were realities throughout Mesozoic time in spite of the fact that they sometimes extended far south of their usual range and at other times were displaced in at least a part of their area by faunas from the south. The alternation of boreal with Indian or Mediterranean faunas in the Jurassic and Cretaceous of the Pacific coast have been well described by J. P. Smith,[7] who made the very plausible suggestion that these faunal changes may have been in large part due to the alternate opening and closing of the Bering Sea passage between the Arctic and the Pacific. Whether these changes in the faunas meant great changes in the climate is not known. The association of ideas is such that boreal instantly suggests *cold,* and Indian or Mediterranean suggests *hot,* but in those distant periods of the past the differences in temperature may not have been and probably were not so great. Whatever may have been the cause and no matter whether it was associated with actual differences in temperature or not, the fact remains that there were boreal faunas in later Jurassic and in Cretaceous time and that there are suggestions of boreal faunas in the Triassic and even throughout the Paleozoic. It is equally true that there were distinctive Mediterranean or equatorial faunas, especially in the Cretaceous. Victor Uhlig,[8] who has studied especially the distribution of Jurassic and Lower Cretaceous faunas, recognizes four faunal realms, boreal, Mediterraneane-Caucasian, Himalayan and South Andean, to which possibly should be added a fifth, Japanese, but he states all these except the first can be combined into a broad equatorial girdle which is contrasted with the holarctic boreal faunal realm.

In this connection consideration should be given to that peculiar faunal facies well developed in several epochs of the Cretaceous, usually called the Mediterranean fauna, which is characterized by the aberrant rudistids and other reef-building pelecypods with corals and distinctive ammonoids and gastropods and in many

[7] Smith, Jas. Pervin, *Pop. Sci. Monthly,* 1910, pp. 482–484.

[8] Uhlig, Victor, Die Marinen Reich der Jura und der Unterkreide, Mittheilungen der Geol. Gesellsch. Wien. Bd. 3, pp. 329–448, 1911.

areas associated with great accumulations of limestone. It is distributed on both sides of the Mediterranean in southern Europe and northern Africa, and is recognized in Syria, India, California, Texas, Mexico, the West Indies and the northern part of South America. The character and distribution of this fauna, or more strictly speaking these faunas, strongly suggests tropical conditions. In Turonian time a special phase of the Mediterranean fauna characterized by Vascoceras and other peculiar ammonite genera has recently been recorded by Reeside in the western interior region as far north as southern Montana. This is in harmony with the known distribution of Metoicoceras, another southern genus of ammonites, as indicating the northward extension of southern faunas in Turonian (early Colorado) time. A little later, at the time when the Niobrara and Austin chalks were being deposited, there are greater differences between the northern and the southern faunas, but whether they were due to climate or to a connection with a northern sea or to differences in the character of sea bottom or to other conditions has not been determined. The Pierre and Fox Hills faunas of the Great Plains and Rocky Mountains region differ still more widely from the contemporaneous faunas of the Gulf and Atlantic coastal plain. The character of the sediments also differs widely in the two regions, and it may be that this fact, together with the probable absence of direct open marine connection, will account for the differences in the faunas.

Just here let me call attention to the chief difficulty in solving our question of climatic zones in past epochs. If the faunas of two regions are identical or closely similar we are justified in assuming that all the conditions under which they lived, including climate, were identical, but if the faunas are different it is very difficult to evaluate all the complex conditions of life that may have caused the difference and to determine whether climate really had anything to do with it. In the first place, it is necessary to be certain that the two contrasting faunas are exactly of the same age. If they are not the conclusions drawn from them as to climatic variations at a particular time will have no value. Then there are questions about the character of bottom, the composition, purity and depth of water, tides, currents and many other things, some of which can be determined with more or less accuracy and some can only be guessed at.

With all these uncertainties in mind and admitting the established fact that during most of Mesozoic time mild climate extended much nearer the poles than at present, it seems to me probable that there was some development of climatic zones with less contrasts than at present, so that the polar regions were somewhat cooler than the rest of the world, and that the warmest seas were in the equatorial region, as they are now.

GLACIAL CLIMATIC CONDITIONS

By Dr. ERNST ANTEVS
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OUR knowledge of the climatic conditions during glaciations is largely gained from studies of existing glaciers and the waning of the last Pleistocene ice sheets. During the growth of ice sheets, when accumulation exceeded depletion, the snowfall over the ice was great and the summer temperature low. Because of cooling of the air over the ice, strong permanent anticyclones were developed here. The precipitation, in accordance with G. C. Simpson's explanation of the snowfall in the Antarctic anticyclone, probably took place owing to the fact that the outblowing air, extremely cooled by radiation, was forced by fast traveling pressure waves to rise over the air in front. It was further cooled in the ascent, so that the water contained was precipitated at insignificant elevation as snow. Since the ice centers, especially those west of Hudson Bay and in Labrador, are now semi-arid or have slight precipitation, there must have been considerable transport of moisture from the seas in low and middle latitudes. Since evaporation probably was not greater than at present, in spite of the fact that the windiness was greater, the unglaciated regions likely received less precipitation than they do to-day.

During the disappearance of the ice sheets the climatic conditions in the glaciated areas must have been characterized by high, and on the whole progressively increasing, summer temperature, strong insolation, clear sky and insignificant precipitation in the form of both rain and snow. High temperature and strong insolation are the most favorable conditions for ice melting; and the depletion of the ice sheets was essentially brought about by rise in summer temperature and insufficient nourishment. Although the retreating ice border was followed by an Arctic tundra belt, the climate was not Arctic, as is distinctly shown by the rapid retreat of the ice borders. This belt was due to the cold ground, the cold winds continuously sweeping down from the ice and the utilization of heat in fusing the ice and heating the melt-water. The precipitation over the tundra belt and the occasional bordering steppe belt was as insignificant as over the continental glaciers. The aridity perhaps was a consequence of the temperature rise, since low temperature near the ground appears to be essential for precipitation in an anticyclone. The deficiency in precipitation on and just outside the ice sheets probably was made up in permanent low pressure areas and along storm-tracks farther away, thus caus-

ing, during the maximum extension of the ice sheets and the first time of ice recession, pluvial periods in the Great Basin, the Mediterranean region, etc.

Of the two decisive factors for glaciation and deglaciation, summer temperature and precipitation in solid form, the first of these is of greater importance.

UPPER PALEOZOIC CLIMATE AS INDICATED BY FOSSIL PLANTS

By Dr. DAVID WHITE
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Cambrian and Ordovician

Prior to the oldest records of land floras of which we have knowledge, paleobotany furnishes little evidence as to terrestrial climates. The blue-green algae were apparently abundant and widespread in the Ordovician and Cambrian formations. According to the views of many paleontologists, they were also represented in earlier periods, many and highly diverse fossils referred with more or less confidence to this order having been found in deposits of pre-Cambrian age. The presence of blue-green algae growing in shallow depths of the sea premises the penetration of sunlight and conforms the testimony both of the marine invertebrates and of the depositional features, which also indicate sunlight and wind in the very early Paleozoic. In this connection mention may be made of the occurrence of corals in the Ordovician and Silurian faunas of the far north, attention being called to the discovery of early Paleozoic formations richly fossiliferous above latitude 80 in the extreme north of Greenland.

Silurian

Slender branching sea weeds, growing erect and provided with structural features enabling them to stand alone in air, appear to have become adapted to amphibious or aerial vegetation for the first time in the Silurian. At least it is probable that the amphibious stage was past before the end of this period, although no fossil remains of algal types or, more properly speaking, of algal derivatives, evidently adapted to sub-aerial growth, are found in formations earlier than the Devonian.

Devonian

Much discussion has been given by many paleontologists and botanists to the emergence of sea plants which presumably found

most favorable environmental conditions in broad shallow tidal estuaries verging into low land marshes in a region of very moist and probably distinctly mild climate. A silicified peat from the older Devonian of Wales presents a biological and geological cross-section of such a very early swamp flora. Both scalariform tissue and punctate tracheids were developed in these early types, and one of them, Nematophycus, the trunk of which must sometimes have reached a diameter of 3 feet, presents a structure embracing rather loosely interwoven tracheids of very large size parted by irregular parenchymatous wedges so as to suggest a gymnospermous relationship. In fact, on the basis of this resemblance, the American material was first described under the name Prototaxities.

The floras of the upper and middle Devonian were of remarkably wide distribution in the northern hemisphere. Genera and even species ranged from the southern Appalachian region and southern Europe to Elsmere Land and Spitzbergen. Little is known of the foliage of the early Devonian land plants. A notable feature of most of the types in this flora is, however, the small size of the leaf, which in some cases seems to have been little differentiated from twig and branch, the latter being apparently flattened or angular so that the whole may perhaps be compared with the phyllodal development. One wonders whether some of the early land plants like Psilophyton (Hostimella) and Nematophycus were not, after all, amphibious. The great thickness of secondary wood in the latter suggests resistance to the pressure of wind and possibly of water rather than an engineering device for the support of a seemingly deficient top.

At later stages, in the Middle and early Upper Devonian, we find in some localities abundant remains of the early arborescent lycopods. These, known under the general term Lepidodendron, were really antecedent to both the Lepidodendrae and Sigillariae, and combine many characteristics of both. They were not large trees and were in general characterized by somewhat ropy-looking, sparsely forking branches, generally drooping; and by thin leaves which persisted for a long time on the larger branches. These leaves are chaffy and sometimes rigid in aspect, but in general they clothe the branches rather thinly, so that the leaf surface of these trees is comparatively small in proportion to the size of the trees. From the meager as well as rather peculiar leaf expansion of the earlier and middle Devonian land plants, notably the Psilophyton group, the inference may tentatively be drawn that less foliar expansion was needed in the vegetation of that day, due possibly to lesser air requirements or, perhaps, to so ample a supply of carbon dioxide that less leaf surface and digestive tissue were needed.

The definite climatic criteria offered by the middle Devonian land floras are scanty. It is, however, to be noted that the cells of certain types of wood of very widespread distribution and of structure referred to by most paleobotanists as gymnospermous, were very large and comparatively thin-walled; and, what is more significant, the wood, which is sometimes found in fragments as much as 2 feet in diameter, shows almost no trace of annual rings of growth.

The known floras of the Upper Devonian were not highly diversified, but they were already relatively highly organized, as proved by the presence of early forms of the cycadofilices. These are fern-like plants, some of which were arborescent, others vine-like, in which varying types of secondary growth were combined with fern-like types of structure, especially in the petioles and foliage. They were essentially flowering plants, since they produced pollen and primitive ovules, foreshadowing, in generally simple forms, the gymnospermous type. The production of pollen on branches separate from those bearing the ovules implies the good offices of winds. The protective covering of the ovules was evidently to safeguard the vitality of the seeds during seasons or on ground unfavorable for germination and growth. Rainfall during the greater part at least of the year is suggested; dispersion by flotation was probably prevalent. The typical Upper Devonian flora was remarkable for its distribution. Its characters are compatible with winds, abundant sunlight and annual or irregular dry seasons, especially in the later stages.

Mississippian

Following the post-Devonian uplift, the Mississippian flora begins with new species of a very limited number of genera, mainly of the lycopod and cycadofilic types, particularly of the genera *Triphyllopteris* and *Aneimites*. In the lowland country this flora was luxuriant, and, where the physiographic conditions were favorable, coals were laid down in swamps, a circumstance which means reasonably ample rainfall.

The early Mississippian flora ranged within the Arctic circle from northwest Alaska to Bear Island and Spitzbergen, as well as into the distinctly temperate zones. In the later Mississippian conditions were in general less favorable for land plants—at least in North America. The floras of this later stage are characterized by reduced foliage, and thick and sometimes recurved pinnules. Carbonaceous deposits are relatively rare. The xerophytic aspect of many of the plants found in eastern North America accords with the evidences of aridity or semiaridity prevailing at times, as is proved

by the deposition of thick masses of anhydrite, gypsum and salt. No luxuriant flora of late Mississippian age has, I believe, been found in any region of the earth. On the other hand, the intervals of greatest aridity in any region were less favorable for the deposition of lacustrine, fluviatile and estuarian plant-bearing deposits. Reduction of the plants was probably consequent to changing environment attending incipient mountain building and changes in the epicontinental seas.

It is probable that the beds of the Caney shale, which in eastern Oklahoma carry ice-transported boulders, belong to a generally inhospitable stage attending the post-Mississippian uplift in this region. Most of the Mississippian species and some of the genera were exterminated during the post-Mississippian revolution. In this last phase of the Mississippian the climate of the world undoubtedly varied considerably, but it can hardly have differed so drastically, with alternating changes, as during the relatively short interval of post-Tertiary time.

Pennsylvanian

From the paleobotanical standpoint the post-Mississippian revolution is in most parts of the world more strongly marked than that following the Devonian. From a meager, stunted and comparatively insignificant late Mississippian flora, there arose in the early Pennsylvanian a very rapid differentiation of land plants, most of which were at the beginning derived from two or three Neuropteroid and Triphyllopteroid genera. In the middle and upper Pottsville (Westphalian age) we have, on the other hand, the most luxuriant and highly elaborated land vegetation of the Paleozoic era. It was the period of very great—possibly maximum—equability of climate throughout great portions of the earth, even in high latitudes, as is shown by the extraordinary geographical range of identical genera and species. Warmth and moisture in amounts most favorable for plant growth are proved by rankness of terrestrial vegetation; great size of trees, plants and leaves; expansion of smooth bark to accompany the enlargement of trunk; large wood cells with thin walls and large intercellular spaces; great size of fronds and the development of aphlebiae—all indicating subtropical or possibly nearly tropical temperatures, in many regions. The absence of rings of annual growth, especially in the upper Pottsville and early Allegheny, points to well-distributed rainfall throughout the year, as well as the absence of winter frost. Abundance of coal predicates relatively copious rain. Fairly well-developed palisade tissue points toward sunlight.

The upper Pottsville, and the Kanawha in particular, are noted for the number of very delicate, laciniately dissected ferns and the presence of many long slender clambering or climbing ferns and fern-like types belonging to the genera Palmatopteris, Sphenopteris and Diplothmema. Many of the ferns were membranaceous, and hydathodes for the elimination of excess water were present in many species and genera. The nearest relatives of some of the ferns are the Marrâtiaceae and Gleicheniaceae which now inhabit tropical and subtropical countries. Other plants are related to the cycads. The Calamariae, the forerunners of the living horsetails, were of colossal proportions and many of them were provided by a thick growth of secondary wood. The evidence for a very humid and subtropical or even milder climate, extending from low to high latitudes, with relatively little annual change in temperature, is cumulative and essentially conclusive. The probable prevalence of winds is shown by large numbers of winged seeds; and the even distribution of rainfall throughout the year is indicated not only by the dilation of the basal portions of the trunks and by the development of knees in some of the trees in accommodation to a permanent water cover over the surface of the swamp, but also by the abundance of the heterosporous lycopods, the successful perpetuation of whose species was dependent upon the conjunction of megaspore and microspore by drift in the water. Further, many of the fruits of the cycadofilic and gymnospermous genera were provided by pollen chambers with closure to assure the success of delayed fertilization.

In upper Allegheny time, which is middle Pennsylvanian, the evidence for seasonal changes is more distinct. Faint annual rings are seen in some of the woods. A little later, however, in the Conemaugh and Monongahela formations, which comprise the upper part of the Pennsylvanian (Stephanian age), we find fairly clear evidence of lack of uniformity of distribution in rainfall throughout the year. Annual rings of growth of the woods are much more distinct. Probable annual dry seasons are indicated by the rapid disappearance of the heterosporous lycopods on account of irregularity or even failure for too long periods of the water to cover the ground of the swamp. Simultaneously we see in what are now the temperate zones the rapid increase of gigantic tree ferns provided with great thicknesses of internal ramenta with notable capacity for water storage. Meanwhile, the delicate membranaceous and clambering or liana-like ferns nearly disappeared and many of the plants, especially in the great genus Pecopteris and its allies, bore rather thick pinnules with coriaceous or villous coverings.

The fact that exactly similar physiological features are shown in the fresh-water basin as in the coastal coal fields, leaves no room for

possible explanation of them as halophytic, though in some cases they may be pseudo-xerophytic. Most of the known floras of the Pennsylvanian were growing in swamps or lowlands of coastal plains or broad inland basins. The period was one of generally well-developed base leveling.

Permian

The most interesting by far, as well as the best known, of all the glacial episodes of geologic history before the great Pleistocene ice age was that which took place near the close of the Pennsylvanian or in the early Permian. This "Permo-Carboniferous" glaciation was widespread in southern India, Australia, South Africa and that part of South America embracing, at least, a considerable portion of southern Brazil. In magnitude it far surpassed the extent of the Pleistocene ice sheets. Glaciation itself is proved by great deposits of till containing unquestionably glaciated boulders. The ice sheets of Africa and South America may not have reached tide level, and in India the glaciers may have moved in a great upland basin. In the Australian region icebergs seem to have broken away along sea fronts.

Within the regions of the influence of this greater cold there was developed a unique flora of curious types known as the Gangamopteris flora, though sometimes inadvisedly referred to as the "Glossopteris" flora. This flora, apparently meager as to variety of types, and seemingly composed largely of forms of low growth and very broad leaves, is found in all the regions where the physical evidence of "Permo-Carboniferous" ice action has been observed. It is distinctly a land flora and, therefore, its distribution, almost in its entirety, from southern India through Australia and South America, premises land connections between these continents as necessary for the free migration of the flora in early Permian time. Similarly, the distribution of some of the very curious types of early Permian reptiles lends support to the presence of such land bridges, the existence of which can, in fact, hardly be doubted. The circumstance that the Gangamopteris flora was at home in regions inhospitable to the cosmopolitan Permian flora of western Europe and America lends support to the hypothesis that migration between some of its habitats, notably between Africa and South America, may have been by way of Antarctica. There is in fact little doubt that this flora, or some of its lineal descendants, inhabited Antarctica at a later period when climatic conditions there were favorable for the growth of arborescent vegetation.

Strong, if not violently contrasting, climatic geography attended the "Permo-Carboniferous" period of cold; for, quite opposite to conditions prevailing in southern Asia and possibly to some extent in north central Asia, the earlier Permian floras in the Appalachian region of the United States were composed largely of Pennsyl-

vanian species continuously surviving, with relatively slight modifications, in the same basins. Here the climate certainly was generally mild in the early Permian. In fact, the change in age from Pennsylvanian to Permian is to be detected mainly through the increasing number of species immigrant from the Permian of western Europe, where the contrast between Pennsylvanian and Permian plant life was somewhat stronger.

On the other hand, the so-called cosmopolitan Permian flora of western Europe and of North America soon showed signs of generally less equability and, in particular, of seasonal variation in climate, with clear evidence of deficiency of moisture in many regions. The vegetation was, however, sufficiently voluminous and the rainfall adequate for the development of thick coals in some of the fresh water basins of France and the Appalachian trough. Well-marked seasonal variation in rainfall is, however, clearly indicated by the almost total extinction of the few remaining heterosporous lycopods, by the prevalence of gigantic tree ferns (Psaranius) with enormous inclosed ramenta and by the development, in moderate strength, of annual rings of growth, though the latter are in general not so sharply defined as in the petrified woods from the province of the Gangamopteris flora. The wood cells are generally smaller, the wood growth being apparently slower.

The fern-like plants which compose the greater part of early Permian vegetation were generally rather thick-leaved, and some have xerophytic features. There is little doubt as to the alternately dry seasons which in western North America soon became of probably far greater consequence than in the east. In fact, the western American flora, to which were added a number of migrants, via the Bering land connection, from Korea, south central China and the Ural Mountain region, suggests seasons of semi-aridity or real aridity. Thus the evidence of the vegetation is essentially in accord with the physical records such as the deposition of great thicknesses of gypsum, rock salt and even potash salts in the western midcontinent and southwestern regions of vast tidal flats and evaporation pans more or less filled with red sands, red mud and salts of different kinds, of Permian age. The greater climatic diversity of the Permian accords with the evidence of continental changes, including especially mountain building, with its consequent effect on the distribution of rainfall.

Knowledge of the later Permian floras is everywhere meager, both because of unfavorable life conditions where land deposits were laid down and because progressive uplift of the land was unfavorable to burial of plant débris in sedimentary deposits. Fern-like plants were reduced in variety and appear in general to have been comparatively stunted. The trees were mainly gymnosper-

mous. Most of the early Permanian types had vanished. The later flora was generated under the stimulus of a changing and somewhat inhospitable environment.

It has been noted that many of the early gymnospermous and cycadofilic plants of "Coal Measures," or Pennsylvanian, time were developed in mild equable climates of copious and well-distributed rainfall. The coming of dry seasons, and possibly of irregular periods of deficient rainfall in latest Pennsylvanian and especially in Permian time, led to the ascendancy of the coniferous stock, and to provision for survival of seed vitality through more than one season unfavorable for germination. This was the period of origin and rapid expansion of Walchia, supposed to be the earliest of the Araucarian stock, which was destined to play an important rôle in the Mesozoic flora, and which is now reduced to a few genera practically confined to the southern hemisphere.

Another interesting order of plants, which appears to have had its forerunners in the latest Paleozoic, is that of the living maidenhair tree or Ginkgo. As my colleague in this program will have pointed out, Ginkgo, the varied species of which became amazingly widespread during the Mesozoic periods, is now reduced to the single species with which we are familiar, it having been for centuries nurtured in the Buddhist Temple gardens from which it has been given back to the world.

In the foregoing paragraphs stress has been laid upon the remarkable distribution of the upper Paleozoic floras which are known to have ranged from low temperate zones as far north as terrestrial sediments were laid down—far within the Arctic Circle. Admitting that our knowledge of the Carboniferous floras is mainly confined to the lowlands of fresh water basins and coastal plains, granting that we have little information as to the upland and mountain floras of the time, and even conceding that there were in the same latitudes areas less hospitable in which land-plant-bearing deposits were not laid down or have not yet been discovered, it is nevertheless unmistakably true that the climates during the greater portions of the Upper Devonian and Carboniferous were mild and comparatively equable throughout a large part, at least of the world, and from low to high latitudes. Some minor changes are to be noted in the meridianal direction, but the general composition of the floras is identical to a remarkable degree.

Relative equability and mildness of climate and great latitudinal range of climate in relative uniformity are, geologically speaking, normal. On the other hand, great climatic differentiation and variability, both seasonal and geographic, are abnormal, and are, I believe, confined for the most part to periods of diastrophic revolution, such as that in which we live. The causes of these extremes and

possibly even of Pleistocene glaciation itself lie, according to the writer's views, largely in the geologically abnormal conditions of continental outline and land exposure now in effect, and in the resulting currents and temperatures of air and water.

It will be remembered that the continents of the northern and western hemispheres now stand high; the continental shelves are to a large extent laid bare, thus increasing the areas of land radiation, and the epicontinental seas—great stabilizers of temperature—are largely withdrawn. Meanwhile, the mountain building of the post-Tertiary revolution is still in progress in portions of the continents, and, in general, mountain ranges may be regarded as comparatively near their maximum average in height. Present land configuration and relief are, therefore, from the geological standpoint, abnormal, and, so, abnormally favorable for great climatic variation and the development of climatic extremes. They are conspicuously different from the generally low relief and the configuration of the notably further submerged continents, more broadly decked by warm continental seas, generally characterizing the greater part of geologic time between the episodes of major uplift.

Minor continental deformation or uplifts, with attending changes in shore lines and epicontinental seas have, of course, occurred from time to time during the great periods of relative uniformity and tranquillity of climate. To the needs for adaptation and adjustment imposed by these environmental changes we owe the great stimulus to organic evolution, and the generation of species and genera of greatest value in stratigraphic paleontology. Several of these changes may have occurred within the really great time represented in many instances by a few hundred feet only of deposits now classified within the limits of a single formation, as is well illustrated by the known variation in the history of deposition of the comparatively thin aggregate of materials laid down during Quaternary time.

While the climates covering the great uplifts or periods of revolution may be compared to that of the present day, they were in most cases not so drastically varied and the extremes were by no means so great as now.

THE SPACING OF ICE AGES AND EARLY PRE-CAMBRIAN CLIMATES

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A GENERATION or two ago it was believed that the earth's climates before the Pleistocene were controlled by its own internal

heat. The nebular hypothesis, as usually accepted, made the earth begin as a sphere of gas which slowly cooled and became liquid and afterwards solid. Finally, a temperature was reached when water could exist and in process of time life appeared in the world and historical geology began. The fall of temperature continued through the successive geological ages until the climax of cold was reached in the Ice Age.

This belief was seriously shaken when proofs were found in India and the southern hemisphere that there had been a more severe time of glaciation at the end of the Carboniferous, from which, however, the earth soon recovered completely. It is now known that times of unusual cold have occurred here and there in geological time as far back as the Huronian.

The evidence mainly relied on to prove these ancient depressions of temperature is the finding of peculiarly shaped stones having scratches on their surfaces. Usually these are enclosed in unstratified clayey material, called boulder clay or till; and when a till is consolidated to rock it receives the name "tillite." These "striated stones" or "soled boulders" are articles manufactured only by ice. No other geological process can make them; so that the finding of typical striated stones is positive proof that a glacier was at work.

Such stones are to be found everywhere in the till of the last ice age and in earlier glacial deposits of different ages, such as the Permo-Carboniferous, the early Cambrian and the Huronian. It is found, however, that wherever these rocks have been squeezed and crushed in mountain building the polish and striae of the pebbles disappear and the tillite may even be changed into a schist so that the proofs of ice work are lost altogether.

Comparatively unchanged sedimentary rocks in which striated stones could be preserved have been found at one point or another in various geological formations down to the Huronian; but all the sedimentary rocks below the Huronian have been so much metamorphosed that it is hopeless to look for striated stones in them.

Are we to assume that no glaciation occurred in the next lower series of rocks, the Timiskamian; or in the lowest of all, the Keewatin, because no striated stones have been found in the boulder conglomerates which occur in both of them?

The Timiskaming sediments are well enough preserved in some places, as at Sudbury, to show much of their original structure, and it is found that thousands of feet are banded with coarse and fine layers an inch or two thick, just like the "varve" clays deposited in lakes in front of the ice in the glacial period. It is certain that there were seasons when the Sudbury beds were laid down, probably cold winters and warm summers. This suggests that the boul-

dery rocks of the same formation may have had a glacial origin in spite of the absence of striated stones.

The older Keewatin Series has been too much deformed in mountain building to supply even this evidence of its climates.

While absolute proof of glaciation may never be found in the most ancient series of rocks, there is one line of evidence strongly suggesting that the thick boulder conglomerates which occur in them were made by ice, like the tillites of later times.

The spacing of ice ages in the better known parts of geological time is peculiar and decidedly interesting. If we run down the table of formations we find that glaciation occurs more frequently in the earlier divisions than in the later ones, just reversing the view once held by geologists. Before the last ice age no important glaciation is known in the Cenozoic, and the same is true of the whole of the Mesozoic; while the two most severe ice ages on record, that at the end of the Carboniferous and that at the beginning of the Cambrian, belong to the Paleozoic, and some glaciation has been reported from all its major subdivisions except the Mississippian.

Much the same is true of the upper pre-Cambrian, and there must have been an important lowering of temperature to produce the many thousands of square miles of ice sheet known to have spread out over the Canadian Shield in Huronian times.

We are sure that liquid water was at work when the earliest known rocks were formed, since they include undoubted sediments; and from the evidence just given, showing that glaciation was more common in earlier than in later times, it is very probable that even in the Keewatin water took on the solid form and glaciers transported the boulders found in the coarse conglomerates of that age.

It may be remarked in conclusion that since periods of cool or even of cold climate are on record at a number of points in the history of the world, reaching back to the most ancient times, there is no geological evidence that the surface of the earth was ever hot.

If the earth began as an intensely hot nebular mass it must have completely cooled down before the earliest known rocks were formed; and the nebular stage, if it ever existed, has little direct interest for the geologist.

THE SOLAR-CYCLONIC HYPOTHESIS AND THE GLACIAL PERIOD

By Professor STEPHEN SARGENT VISHER
INDIANA UNIVERSITY

EXPLANATIONS of changes of climate such as the glacial periods indicate have been numerous. Three historically important hypotheses may be briefly stated. (1) According to the elevation

hypothesis, the continents during the glacial periods were much more elevated than now, high enough so that the glaciated portions corresponded with the snow-covered mountain tops of to-day. (2) The possibility that the *poles* may have wandered sufficiently so that the ancient glaciated areas, southern Illinois, for example, were subpolar, has been repeatedly suggested. (3) According to the much more carefully developed hypothesis of Chamberlin, the atmospheric composition and the oceanic circulation have varied from time to time in such a way as to produce radical changes of climate. Other writers have attempted to explain changes of climate by assuming variations in the ellipticity of the earth's orbit, in the amount of heat given out by the sun, in the distribution of land and water and in the intensity of volcanic activity.

Most of these theories were developed before a large body of facts relating to ancient climates was available, or else were offered by persons not familiar with the geologic evidence. When they are tested by the facts now known as to the irregular distribution of the ice sheets of the last great ice age, the alternation of glacial with mild interglacial epochs, and the contrasts among the several glacial epochs, they are seen to be inadequate. By far the best is Chamberlin's, but that hypothesis is unable to account for the more sudden climatic changes indicated by repeated pauses in the retreat of the ice sheets (shown by the recessional moraines), or for the irregularity and certain other features of the mild interglacial periods. Professor Chamberlin himself admits the inadequacy of his theory in these regards.

In 1914, Ellsworth Huntington, of Yale University, turned his attention to the possible causes for these changes. He recognized that there has been insufficient change in the altitude of the continents, in the distribution of land and water, or in the position of the poles to cause the observed climatic changes. The length of time between the changes was, in many cases, altogether too short to warrant the assumption that there had been a significant change in either the percentage of carbon dioxide in the atmosphere, or in the direction of the oceanic circulation. Hence he began to consider the possible terrestrial effects of solar changes. A "solar hypothesis," that variations in the amount of heat emitted by the sun produce the observed climatic changes on the earth, had been advanced long before by Blanford, Lockyer and others, but it did not seem satisfactory, because a mere variation in the amount of heat apparently could not account for the complex changes of terrestrial climate.

The possible climatic significance of variations in storminess occurred to Dr. Huntington. The reason for this was that his

studies had led him to conclude that only slight changes in mean temperature have occurred during the last 3,000 years, whereas fairly large changes of rainfall appear to have taken place. The rainfall in the eastern Mediterranean lands and Central Asia, where the chief evidence of climatic fluctuations in historic times has been found, is almost wholly cyclonic. Therefore the best way to account for its variations seems to be by changes in the number, intensity and paths of cyclonic storms. Searching about for discussions of this subject, he found that cyclonic storms had been almost entirely ignored by writers on climatic changes. Nevertheless, a consideration of their probable climatic importance and some evidence of their variation at such periods as the fourteenth century led him to suspect that they were important factors in glacial as well as historic fluctuations.

The solar-cyclonic hypothesis has two phases: (1) that variations in storminess produce important changes of climate, and (2) that solar changes somehow lead to changes in storminess. The effective focussing of attention upon the climatic significance of cyclonic storms is a contribution of high value to the discussion of causes of climatic changes. This is illustrated by the fact that such opposed investigators as Humphreys and Chamberlin, who formerly ignored storms, now make large use of them in their modified theories. They are convinced that storminess is important. Some of the effects of increased storms in any particular region are (1) the cooling due to increased cloudiness, precipitation and winds, (2) differences in the distribution of precipitation and (3) increased evaporation and precipitation resulting from increased wind velocity. A fourth effect is the influence of storms upon the northeastward movement of warm waters in the Gulf Stream Drift and similar currents.

The second phase of the solar-cyclonic hypothesis is that solar changes produce changes in terrestrial storminess, and that if the changes of storminess observed during a sunspot cycle to-day were intensified and magnified sufficiently in the past, some of the aspects of ancient climates which have hitherto been inadequately explained would have been produced. Conditions during a sunspot maximum are of the glacial type and those of the sunspot minimum of the interglacial type. During a sunspot minimum storminess decreases, at least in high latitudes. If, during certain epochs in the past, there were almost no storms, climatic conditions would have been notably different in certain large regions. For example, most of the United States east of the western mountains would be arid because then the westerly winds would prevail, and such winds would lose their moisture in crossing the western

mountains. The rain and snow of the eastern half of North America are practically all brought from the Gulf of Mexico, and precipitated by cyclonic storms. If there were no storms, and hence no precipitation, there could be no glaciation in eastern North America. Hence, if during the glacial period, storminess for some reason decreased greatly or disappeared, the glaciers covering much of northeastern North America would necessarily promptly diminish from lack of snowfall and an interglacial epoch would be inaugurated. In northwestern Europe, on the other hand, a decrease in storminess would mean a greater warming in winter because of the stronger southwesterly winds and the associated more rapid movement toward Europe of the warm waters of the Gulf Stream Drift. The European glaciers would disappear during an interglacial epoch therefore by melting rather than by evaporation.

Changes in storminess will not explain all the facts of ancient climate. Changes in land elevation and distribution, in the composition of the atmosphere and ocean, and in the direction of the oceanic circulation are also important. Furthermore, other agencies may have helped produce the numerous complex changes of climate or aspects of climate revealed by the geological record. Nevertheless, the solar-cyclonic hypothesis has effectively pointed out the climatic importance of cyclonic storms and hence of changes in storminess, it has offered a plausible explanation for certain hitherto inadequately explained phenomena, including the suddenness of some of the minor climatic changes and the occurrence of mild interglacial epochs in the midst of a glacial period, and it has stimulated further study of the subject of ancient climates and climatic changes by bringing a new and helpful factor into the field.

CAN WE EXPLAIN GRAVITATION?

By WALTER D. LAMBERT

U. S. COAST AND GEODETIC SURVEY

SIR ISAAC NEWTON did not discover the force of gravitation. Multitudes before his time had seen apples fall and had noted that falling to earth is the regular habit of inert unsupported bodies. Long before Newton, scholars had generalized these results of observation into the statement that bodies are attracted towards the center of the earth. What the fall of the apple did—if we accept this somewhat apocryphal tale—was to stimulate Newton to consider whether the attractive force might not extend beyond the earth far enough to govern the motions of the earth's nearest neighbor, the moon. His calculation showed that, if terrestrial gravity were conceived as varying inversely as the square of the distance from the earth's center, it would explain the motion of the moon around the earth and that a similar force would explain the motion of the earth and of the other planets about the sun. The patient studies of the elder Herschel on double stars showed, as had been anticipated, that the same kind of force appeared to govern their motions also.

Just because the effects of gravitation are so familiar and because Newton's law accounts so completely for the motions of the heavenly bodies, except for a few minute effects which Einstein's theory represents better than Newton's, we are apt to forget how mysterious gravitation is and how little our so-called explanations penetrate the mystery.

Between ordinary objects the attraction of gravitation is very small, between bodies of astronomical dimensions very great, in spite of the immense distances that usually separate the latter. Suppose, on the one hand, two spheres, each one inch in diameter and made of osmium, which is the heaviest known metal, being twice as heavy as lead, and suppose them to be placed at rest two feet apart. Under the influence of their mutual gravitational attraction and with all resistance to their motion absent, it will take about one day and five hours for them to come into contact. To those not familiar with the cumulative results of very small forces working unopposed over considerable periods the time required for the two balls to come together may give a very inadequate idea of the minuteness of the force. When the balls are two feet apart, the force between them is 0.000 000 67 dyne. An illustration will give some idea of just how small this is. Take the metal in an ordi-

nary silver dime, which weighs 2½ grams, or less than one tenth of an ounce, and draw it out into wire fine enough to extend all the way around the earth. The force between the two spheres of osmium referred to above will be less than the weight of one half inch of this fine wire.

On the other hand, between bodies of astronomical dimensions the forces are almost incredibly large. If the gravitational pull of the sun on the earth, which is the force that maintains the latter in its orbit, were to be exerted by means of a cable having the tensile strength of ordinary structural steel, in order barely to escape rupture the diameter of the cable would have to be about three quarters the diameter of the earth. This calculation supposes the material in the cable itself to be destitute of all power of attraction, either on itself or on other bodies. If the cable were of ordinary attracting matter, the stresses would be enormously greater, quite beyond the power of any known material to sustain.

The force of gravitation differs from all other known forces. It is not affected by the motion of the attracting bodies, as electrical forces are. It is not dependent on the nature of the attracting matter, only on its mass and position. Efforts to detect a change in attraction corresponding to changes in temperature have failed.[1] Gravitation appears to be transmitted instantaneously to all distances and not to be screened off in any way by the interposition of matter of any kind.

What do we mean by an explanation of physical phenomena like those of gravitation? Our so-called physical explanations are almost always mere descriptions of one sort or another and do not attempt to elucidate the "ultimate whereforeness of the thusly." The description may be a mathematical rule that can be applied to deduce certain conclusions. If these conclusions are found to be in accord with observation, we say that the explanation is a good one, so far as it goes, and the wider the range of observation facts embraced and the more diverse they are, the more satisfactory do we consider the explanation. Such is Newton's law of gravitation. It is a mathematical process that can be used to predict with great accuracy the complex movements of the moon, planets and stars. Where it has appeared to fail slightly, a more rigorous examination has almost always shown the mathematical analysis and not the law to be at fault. The chief exception is the famous question of the perihelion of Mercury's orbit. So far, all

[1] Theoretical considerations brought forward by Einstein, but not necessarily dependent on his theories of relativity and gravitation, indicate a very small decrease of attraction with temperature, much too small to be detected by present means.

attempts to explain completely the motion of the perihelion by Newton's law have been unsuccessful, unless suppositions are made that would imply serious perturbations in the motion of other planets, perturbations which are not verified by observation. It is one of the triumphs of Einstein's theory that it succeeded where Newton's failed.

But a mere mathematical formulation, however comprehensive it may be, however many diverse consequences it may contain implicitly packed away in a few brief general statements, and however closely those consequences may correspond to experience, does not by itself completely satisfy our minds. We like a working model of our law, something analogous, though perhaps on a molecular scale of magnitude, even an atomic or electronic scale, to the mechanisms of every-day life. We like to see the wheels go round. In this respect the explanations of both Newton and Einstein fail to satisfy. They give a basis of calculation but they do not illustrate. To transmit the vibrations of light and electricity, physicists imagined the ether, but to make it perform satisfactorily they had to endow it with properties very different in degree from those of any known material. But what medium shall we conceive that will transmit gravitation instantaneously to all distances, unaffected by the physical state of the attracting bodies or by any interposed matter?

The difficulties of constructing, mentally, a working model of gravitational attraction according to Einstein's law are quite as great. Einstein makes gravitation a property of a certain non-Euclidean space of four dimensions, one dimension of which is imaginary time, and this imaginary time is assumed to be indistinguishable in kind from the other dimensions.[2]

We have been thinking so long in terms of the Euclidean geometry that we find it nearly, if not quite, impossible really to visualize non-Euclidean space even of three dimensions. The so-called four-dimensional geometry is merely mathematical analysis with four variables, analysis having certain analogies with an analysis of three variables that can be interpreted geometrically in terms of three-dimensional space. It thus seems natural to use geometrical language in connection with our calculations on four variables, but when all is said and done, it is really analysis that we have

[2] This idea of time as a fourth dimension did not originate with Einstein. It was put to practical use in obtaining solutions of certain differential equations of mathematical physics by the late R. A. Harris, of the U. S. Coast and Geodetic Survey, and by Professor Whittaker, of Edinburgh. This was merely a mathematical device, justified by its results, and was not made the basis of any general physical—or metaphysical—theory.

and not geometry as the ordinary person understands it. What with the non-Euclidean nature of the space and the added dimension, the task of obtaining a mental picture of the workings of gravitation is difficult indeed. It is even maintained that, properly to state the matter in Euclidean terms, ten dimensions are necessary.

Neither Newton's nor Einstein's theory gives us a working model of gravitation. Both of their theories are in effect simply rules of calculation, although—to be fair to Einstein—it should be said that the development of his theories required, in addition to great mathematical skill and knowledge, a wide acquaintance with the results of experimental and theoretical physics and a familiarity with that region of thought where physics merges into metaphysics. Einstein's rule gives, in most cases, results substantially the same as Newton's, although, where they differ by amounts accessible to observation, the results of the Einstein theory accord better with experience than do the results of Newton's. Einstein's theory embraces a wider range of phenomena and, on this account also, should be given the preference. But it requires much more complicated calculations than Newton's theory, and its basis is much more remote from our ordinary ways of thinking than even Newton's mysterious force, so remote that the statement of it easily runs into paradox. But the paradox is not entirely due to Einstein or his expositors. In some respects nature herself seems to play the paradoxer. It is doubtless this seemingly paradoxical quality that has aroused the popular interest in it. Generally the man in the street concerns himself not at all with an abstruse scientific theory, but when the air resounds with the dispute between the adherents of the older and the newer theories and paradoxical statements fly thick and fast, the man in the street looks on with a real, though puzzled, interest.

Einstein's theory, however, is so successful as a basis of calculation that there "must be something in it" but just what that "something" is we do not clearly see. Perhaps we may get used to thinking in Einsteinian relativistic terms, or perhaps some more general form of statement will be found which will include those parts of the Einstein theory that are valuable as a basis of calculation and which will, at the same time, be expressible more nearly in terms of our present, every-day ideas of time, space and force. Meanwhile, we can merely calculate and describe the effects of gravitation, but we can not really explain it. But, if and when that time comes, will the new "explanation" be anything more than a description, a description perhaps in terms more exact, more compact, more familiar or more comprehensive, but still only a description?

THE COLUMBIAN GROUND SQUIRREL AS A HANDLER OF EARTH

By WILLIAM T. SHAW
WASHINGTON EXPERIMENT STATION[1]

LIVING in tunnels which he himself excavates in the earth, it is not surprising that the Columbian ground squirrel (*Citellus columbianus columbianus*) has reached considerable skill as a handler of soil. My attention was first attracted to his capable methods of doing this while making quiet observations upon this squirrel in observation yards which had been constructed for its close study.

These exhibitions were generally given at the entrance of a burrow where a mound was being piled. Frequently a squirrel would appear at the mouth of one of these holes looking somewhat ruffled, and progressing backwards with his burden of earth. In handling it he would proceed after this fashion. Placing his hind legs firmly and widely apart, he would dig very rapidly with the front feet, packing the loose dirt up under his belly. Then he would kick it back with his hind feet, alternately right and left, quite rapidly, though not so quickly as with the front feet. At this time one would see a shower of earth being shot swiftly to the rear, and the body of the squirrel sink simultaneously into the trough under him, made by this displacement. Not infrequently, after the earth had accumulated into a considerable heap behind him, he would turn and ram through the mound, with his nose, plowing the loose dirt ahead, soon emerging with the short stiff hairs of his face bristling with earth particles.

Of course to observe his methods of handling soil in the depths of his den was more difficult. On March 10, 1917, we had a good opportunity of observing this while digging for a recently awakened hibernating squirrel. He had escaped from the nest into the drain and was digging rapidly in an effort to escape. He would dig with a very rapid movement of his front paws, sometimes bracing his shoulders against the walls of the burrow and digging sidewise, much like a dog will do when after some large burrowing animal. When considerable earth had been loosened and became too much in the way, he would turn about in his cramped quarters and ram it back with his nose, thus firmly plugging the passage behind him.

In making the tunnels in the dens it is probable that not all the earth is brought to the surface, but is deposited in some unused

[1] Published with the approval of the director of the Washington Experiment Station, as Scientific Paper, No. 119, College of Agriculture and Experiment Station, Pullman, Washington.

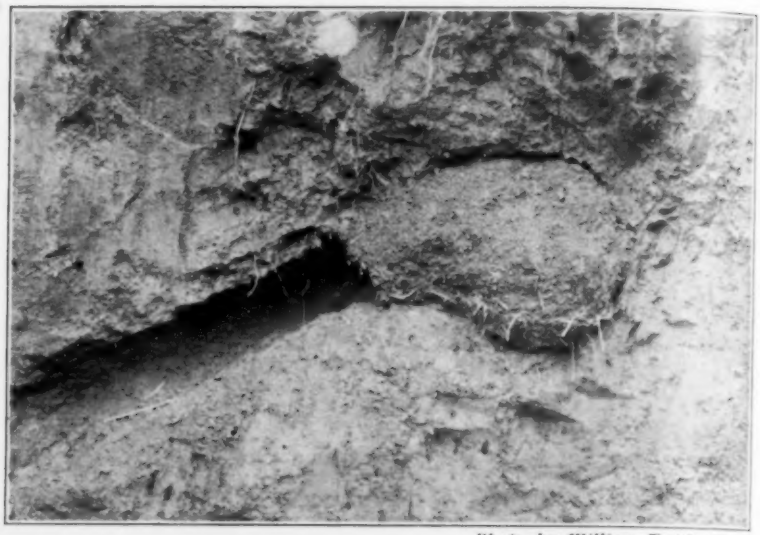

Photo by William T. Shaw

FIG. 1. FILLED HIBERNATION CELL

In the dens of ground squirrels it was not unusual to find old hibernation cells, burrows, and drains, compactly filled and tamped with earth, so solidly placed that it could be excavated and still remain as a mass.

Photo by William T. Shaw

FIG. 2. A PLUGGED BURROW

Oftentimes in excavating squirrel dens, it was found that many of the burrows were plugged with earth. The illustration shows one of these at a point where the work of plugging ceased. The pits, looking like finger tip depressions, are made in the soft earth by the nose of the squirrel in tamping.

burrow, nest-cavity or cell (Fig. 1). Many of the holes which appear on the surface of the ground without any fresh earth about them may be accounted for in this way, they having been excavated from below. Indeed it would seem that they are all originally made in this way.

It is very noticeable that much of the digging of earth is done in the spring and early summer when the ground is still soft. It has also been observed that much earth is thrown out of the dens after rain showers, as if the squirrels employed themselves in this way when the weather would not permit of their being outside. On May 8, it was noted that five holes out of eight in a den had fresh dirt thrown out of them from the burrows within an hour after a shower.

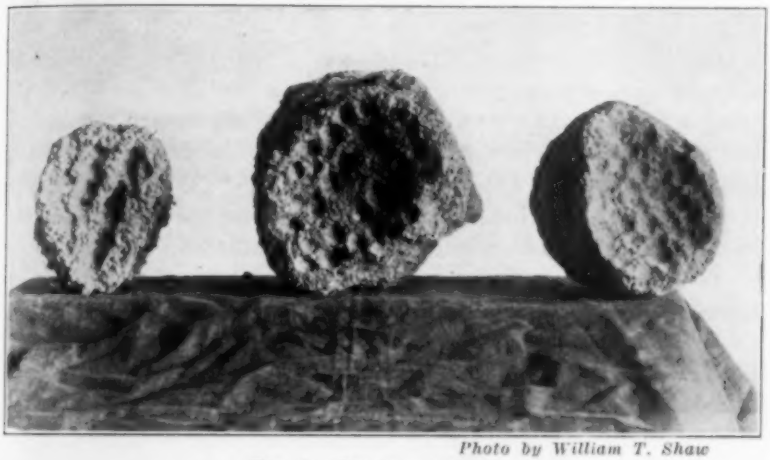

Photo by William T. Shaw

FIG. 3. TYPES OF PLUGS

In this illustration three types of plugs are used. On the left is a plug made when the earth is moist and soft, allowing the impression to be made much deeper. To the right is a closing-in plug taken from a hibernation den, where of necessity dry earth of the season had to be used. The plug in the center made from medium moist earth is a typical example of this kind of work, showing clearly the nose prints of the worker.

They seem to be methodical in their operations, as it was noted that three captive male squirrels in the yards completed the excavations for a den in their yard and, having this finished, suddenly transferred their nest from the box thereto.

But a much more remarkable use they have developed for disposing of loose earth in their burrows is found in the plugs which they construct within the burrows themselves at various depths and at different places. Early in the investigation of the dens of this squirrel, by the writer, at Pullman, Washington, it was noticed that the burrows were in many cases plugged and ob-

structed with earth (Fig. 2). At first it was thought that this was due to water washing soil down into the holes, or that it might have been due to the work of the pocket gopher, an animal frequently inhabiting unused squirrel dens. These plugs were, however, rather too solid to be made in either of these ways, being so firm that they could be completely excavated from the tunnels in which they were placed (Figs. 3 and 8). There was a regularity in which they broke into disk-shaped layers (Fig. 4). They were pitted on the concave side and covered with corresponding elevations on the convex. It was concluded that this was done by pressing the moist earth into place with the nose as is done by the prairie dog.[1] As these plugs were found constantly both in the summer dens as permanent structures (Fig. 5) and in the hibernation dens as temporary obstructions (Figs. 6 A, 7), it is proposed to consider them at some length.

One reason for this plugging is protection. Here the cavity of a brood nest may be protected by having one or more of its entrances closed by this peculiar sort of squirrel masonry. A second use of the plug is in reconstruction of a hibernation cell where only one entrance is needed. A further use of the plug, especially the temporary plug described below, is to close the entrance of the burrow in order to keep out cold or a threatening present danger.

It is not uncommon to see these plugged burrows exposed in newly made road cuts or basement excavations, even in the center

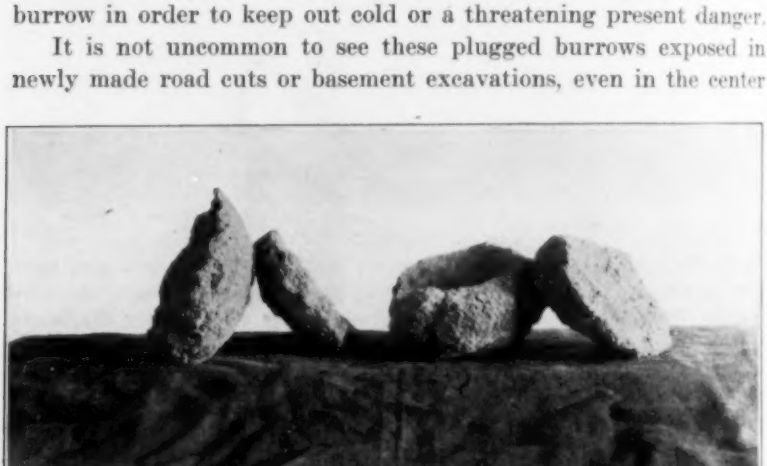

Photo by William T. Shaw

FIG. 4. SAUCER-LIKE LAYERS OF A PLUG

Each quotum of earth as it is brought to the scene of burrow plugging is tamped firmly against the preceding one. By careful effort these may be broken apart, showing nose pits on their concave and corresponding elevations on their convex sides.

[1] Merriam, Yearbook, United States Department of Agriculture, 1901, p. 260.

Photo by William T. Shaw

FIG. 5. RECONSTRUCTION OF DENS

The nest cavity on the right is now guarded from approach by the plugging of the two burrows leading to it; the one under the handle of the knife and the other at its tip. In this way the nest cavity is made much more safe.

of the town. They frequently look as fresh as the day they were made.

It is almost never done outside of the den, as it is in the case of the prairie dog. Only once have I noticed this. A squirrel, supposedly digging, was observed. Wishing to see what sort of bulb it was after I frightened it away. Strange, but the supposedly digging squirrel, which reluctantly left its task, was found to have been tamping the moist dirt down into a pitted saucer. It was plainly the work of the nose. On digging to see what it had buried, I found, about three inches down, a large open burrow. This burrow had come up from the inside into the middle of a cow path, and fearing disturbance, the squirrel had plugged it from the inside first and then had undertaken to make the job more complete by tamping it on the outside. The inside of the plug was concave and showed signs of nose prints. Of course to observe the operation below in the dens was difficult. Generally, however, there is enough loose earth in the bottom of a burrow to furnish material for a hastily constructed plug in case of pursuit.

In the spring of 1914, while working on the extermination of the ground squirrel with gas, we not infrequently came upon short temporary plugs inserted in various places in the burrows (Fig. 6, A). These plugs were placed in the burrow chiefly to prevent the cold air of the chill spring evening from entering.

This form of plugging was noticed on February 26, in a den on a cold north slope. On the 27th about 3:30 P. M. we went to dig out the den. Down the exit shaft about a foot we came upon a soft earthen plug obstructing the passage. The squirrel had dug a little pocket in the side of the burrow where it is supposed it got the earth for the plug, as the soils in the pockets and the plug were the same. This may account for the formation of the turning pocket, a small cup in the side of the burrow where they turn to reappear again at the mouth of the burrow after having been frightened in. The plug itself was quite firm and showed signs of nose prints where it was packed in concavely from below.

Again on March 5, a workman saw a squirrel enter a hibernation exit. To make sure it would not escape he placed a board over the hole. An hour later the den was treated with carbon bisulphide. We were later surprised to find the squirrel had put in a short plug two feet eleven inches below the entrance, just above the nest entrance.

On March 6, a hibernation exit was found and a straw placed across its entrance to tell if the den were still inhabited. The following morning on examining this exit it was found that it had been plugged from the inside, the fresh dirt being pushed up until it just touched the straw. It was left as it was for observations and by eleven o'clock in the morning the hole had been opened. The squirrel, a female, was afterwards killed by carbon bisulphide. At least six cases were found in the fields and yards.

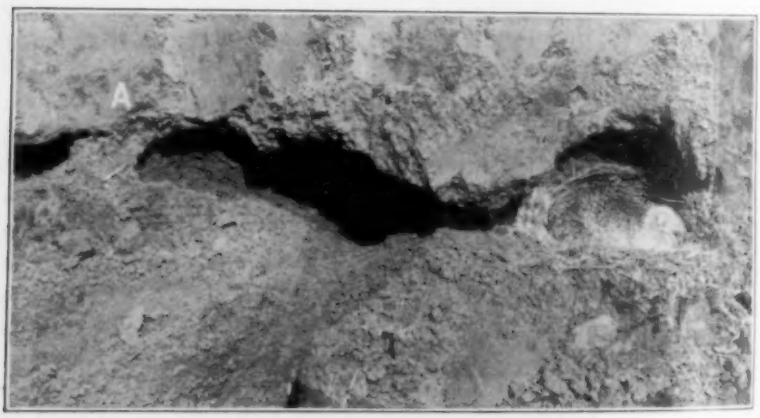

Photo by William T. Shaw

FIG. 6. A TEMPORARY PLUG

In the spring when the air is still cold the squirrel closes the entrance to his nest by tamping in a temporary plug which may be located at various places in the shaft leading from the nest to the exterior. Such a plug is shown at A.

Photo by William T. Shaw

FIG. 7. TEMPORARY PLUG

This figure gives a close view of the plug shown at A in Fig. 6. On the right side, next to the nest, the nose prints can be plainly seen. The plug is about three inches thick.

Photo by William T. Shaw

FIG. 8. A CELL PLUG

This plug, taken from a hibernation cell, is hard and durable, even resisting the light stroke of the pick when being broken. Nose prints in the center of the figure show clearly where the work ceased at the neck of the cell.

With these and subsequent observations in mind, it is thought that the temporary plugs are chiefly used in the early spring, as they were not noticed in the burrows later in the summer. On cold days there is not much activity among these recently awakened squirrels. On March 1, a cold wind springing up during the afternoon (Temp. 37 degrees F.) caused the squirrels to put plugs in the exit shafts. An exit was found and a straw placed across it in the forenoon. In the afternoon of the same day the squirrel had not left the den but had put in a plug below the straw. That they use the plug for protection seems probable. One late afternoon I saw a squirrel disappear from the perfectly plane surface of a field. I walked at once to the spot and found an exit. In the very short interval of time it had put in a small plug, which came about an inch below the surface. Was this plug to ward off danger or to keep out the cold of the approaching night? A similar instance was observed on March 3, a bright warm morning. A large squirrel was seen standing in the erect, watching position, halfway across a 20 acre field. As I approached it ran and disappeared in a hibernation exit which had about one third of its diameter plugged from the inside. This plugging was done on a sunny morning and would indicate that the plug was a protection against an approaching enemy.

It was later found that two plugs are sometimes used in the same exit shaft. In the spring of 1917, an exit was observed on March 6, and on the 8th it was stopped by a soft earth plug placed within an inch of the ground surface. The day was raw and a little wind blowing. On the 10th we went to examine this den and found it still plugged. The plug was dried on top as though it had not been disturbed since the 8th. We opened the plug and ran a cane down full length at an angle of 45 degrees. On digging we broke into the exit shaft and about 30 inches below the first plug found a second one. This plug was placed like other temporary plugs, and was about 3 inches thick. Occasionally this tendency to plug was shown about the boxes in the observation yards.

When considering the nature of their habitat, it is not surprising that they have become skilful and resourceful in the use of the material at hand, as have other rodents such as beavers, with the material of their environment.

CHROMOSOMES, ENDOCRINES AND HEREDITY

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THE word "heredity" has had various connotations at different times. Very early it was recognized that the children are the heirs of certain traits of the father and mother and hence arose the primitive conception of heredity. Studies of genetics during the past quarter of a century have established the idea that what is inherited is not the visible traits of the parents (the phenotype), but the genes of such, which are carried in the germ cells (the genotype). With the recognition of the importance of the genotype in heredity attention has been directed to the genes themselves as they are located in the germ cells; and during the last fifteen years there has developed a new conception of the rôle of the chromosomes as carriers of these genes. On the one hand, through the remarkable studies of T. H. Morgan and his associates, the architecture of the chromosomes is being determined in detail so that maps can be drawn indicating graphically the relative linear position of these genes in the chromosome. An example of such a chromosome map is shown in Figure 1, which indicates the relative position in the first chromosome of the genes responsible for a large number of mutations which have been found in the banana fly, *Drosophila virilis*. Whenever a particular abnormality appears in the eyes, wings or body of this insect, a corresponding change apparently has occurred in the material occupying a particular point in the particular chromosome in which is located the material chiefly responsible for the production of that abnormality. This discovery marked so great an advance in our knowledge of heredity that it is not strange that in his enthusiasm the principal investigator in this field should have exclaimed: "The problem of heredity is solved!"

However, it has not been possible to explain all mutations on the ground of the modifications of the genes lying in the chromosomes. On the contrary a series of mutations have been worked out, chiefly by A. F. Blakeslee and John Belling, which depend upon modifications in the number of entire chromosomes. In the Jimson weed, *Datura stramonium*, which has normally 12 sets of chromosomes, 2 in each set, the 12 pairs of chromosomes obviously carry, like the different chromosomes of the Drosophila, each its special

genes. These chromosomes differ thus in structure as indeed they do in size so that we can recognize chromosomes a, b, c and so on. Now if the chromosome "Set a" comprises, as it occasionally does, 3 chromosomes instead of 2, there is a corresponding difference in the form of the Jimson weed. If "Set b" has the extra chromosome, still a different form of plant results. If "Set c" is the one that has the additional number still another form and so on. By the addition of one extra chromosome to each of the 12 sets we may have produced, in turn, 12 different kinds of Jimson weeds. In rare cases 2 extra chromosomes may be added to each of 2 of the sets and thus a new set of modifications of form may be brought about, or a chromosome may be subtracted from one of the sets or may be subtracted from one and added to another set. Again all the sets may be represented by one chromosome only instead of 2 each. Or all the sets may include 3 chromosomes or 4 chromosomes. These are possibilities which permit the plant to survive. Many others are thinkable which probably may cause an early death of the plant. In Figure 2 we have a diagram taken from Blakeslee's work, showing some of the different types of variations in the chromosome number; and corresponding differences in form of seed-capsules of the plant.

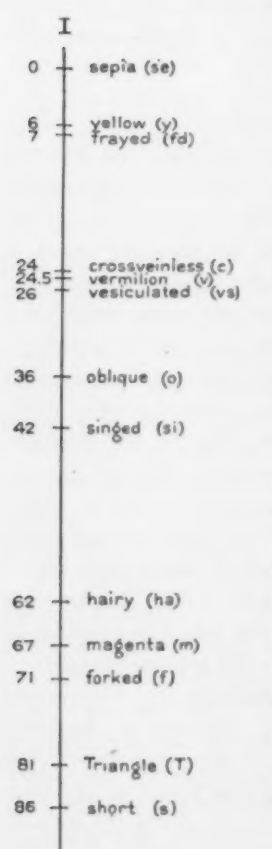

FIG. 1
CHROMOSOME MAP
of sex chromosomes of *Drosophila virilis* (Dr. C. W. Metz)

The relation between structure of the chromosomes—of mutations in its constituent genes, on the one hand, and, on the other, the relation of variations in the number of whole chromosomes or fragments of them, to mutations, seems to justify the conclusion to which the man in the street comes in contemplating the findings of the geneticist, namely, "We are what our chromosomes make us."

The findings of the geneticist are further supported by the similar observation of resemblances between different members of a family. This resemblance is frequently striking among brothers and sisters of one

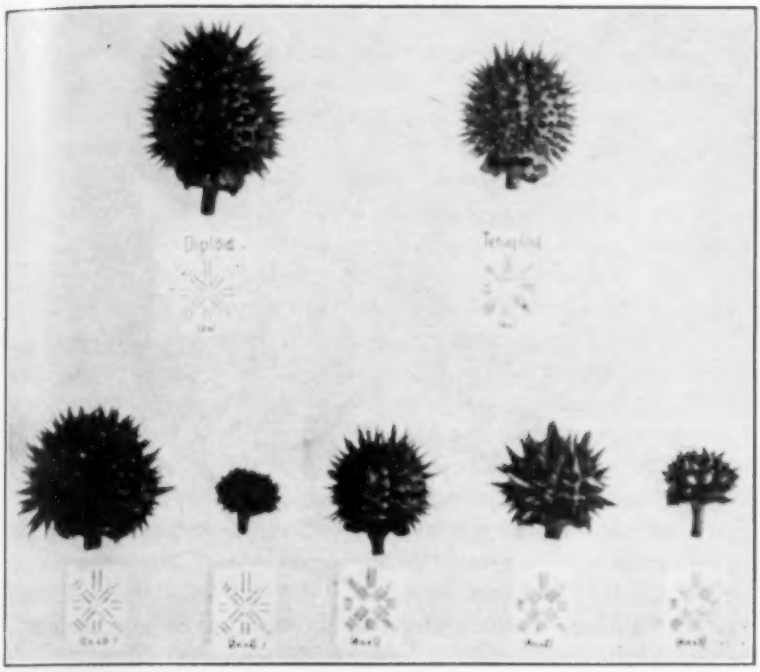

FIG. 2. CAPSULES OF FIVE GLOBE MUTANTS
and corresponding chromosomal complexes. (Dr. A. F. Blakeslee)

fraternity. That it is not more striking—that brothers and sisters so often show points of difference—is due to the fact that the germ cells of the father and of the mother are not at all alike, but may be very diverse, just because of the hybrid nature of their ancestors.

There is one phenomenon, however, of striking similarity which has long been noticed and this is the phenomenon of identical twins. Here we have pairs of persons who resemble each other so closely in form and features, in behavior, in resistance to disease, that they are frequently almost indistinguishable. Even their own parents may confuse them. Example of such pairs of twins are shown in Figure 3. Now this great resemblance of identical twins is commonly explained on the ground that they are derived from one and the same egg which has produced by budding upon its surface two embryos in the place of one. This view is supported by the fact, among others, of a certain peculiarity of identical twins that distinguishes them from other twins in that the embryos at birth are enveloped in the same envelope, called chorion, whereas in ordinary twins there are two distinct chorions. Since such twins are derived from the same egg and hence from identically the same chromosomes, the view that the chromosomes are the basis of familial similarity is supported. It is, indeed, a

natural extension of this finding that we should ascribe not only family but also racial resemblances to identity of genes which determine the production of these racial characters. Individual differences, on the other hand, are due to mutations in genes of minor importance. Family resemblance and racial resemblance depend on similarity of chromosome composition. Resemblance is proof of "blood" relationship; more strictly chromosomal identity.

There is, however, another set of facts which must not be neglected. In an institution for the feeble-minded one may see a number of persons having a striking similarity which enables us to say at sight that they are cretins. A photograph of several such cretins is reproduced, Figure 4. Resemblance between them is often, in general, as great as that between members of the same European race and individuals who do not belong to the same family may be as alike as two brothers. In the case of cretins the peculiar and differentiating characters that they show are generally ascribed to the fact of an endocrine disturbance. Their thyroid glands are not functioning normally and hence the similar peculiarities in form that they show.

Still another class of defectives shows an even greater resemblance. This is the class of mongoloids, so called from their resemblance in features and bodily proportions to the Southern

FIG. 3. FOUR PAIRS OF TWINS
(White Studios, N. Y. City)

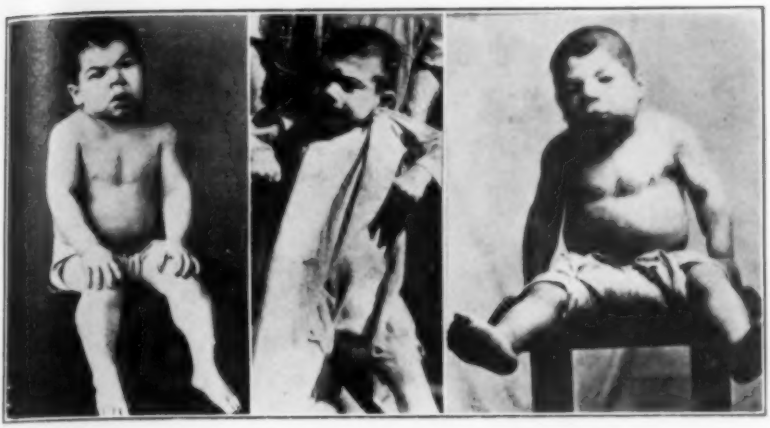

FIG. 4. THREE YOUNG CRETINS, UNTREATED

Chinese. Figure 5 is a photograph of three such. The resemblance between these people is often very marked, so much so that the matron in a building where several of them reside and who sees them very frequently, almost constantly every day, states that she frequently confuses them. This is the same sort of resemblance that is exhibited by identical twins, the resemblance which has been used by Galton and others as the strongest evidence for the superior influence on development of nature over nurture. Yet two of the mongoloids in question belong to different European races. Children of Northern Europe and Southern Europe may be almost indistinguishable. The cause of mongoloidism has not been ascertained. It is probably due to some endocrine disturbance in the mother, since the defect is already shown in the children at birth. Whatever the abnormal condition in the mother of these mongoloids it is probably normal for the mothers of the typical Southern Chinese, for in almost every respect, excepting intelligence, the resemblance between the mongoloid dwarfs and Southern Chinese is very close. A consideration of the facts of cretins, mongoloids and other types of the feeble-minded whose later developmental impulses, of endocrine origin, are evidently abnormal might indeed lead to the conclusion that "we are what our endocrine glands make us."

The tremendous importance of endocrine glands in controlling the later development of organisms has been brought home to us by the studies of the last two decades. It is known that the transformation of the tadpole into the frog is effected only in the presence of the thyroid gland in the tadpole. For if this gland is removed, metamorphosis fails to occur though growth continues. Again the pigmentation of the young amphibian depends upon the

FIG. 5. PROFILES OF THREE MONGOLOID IMBECILES
Of two different racial stocks; left Scotch; middle and right, Russian Jewish

secretions of the pituitary gland, since when this is removed the animals are albinic. In humans, also, special disfunctioning of the pituitary gland leads to excessive growth in length of the legs, on the one hand, or to excessive obesity, on the other. Unquestionably the secretions of some of the endocrine glands have a most important effect upon the metabolism on which development depends. It is no wonder that the endocrinologist finds in the hormones the principal agency of family resemblance.

How can the difference between the views of the geneticist and the chromosomologist, on the one hand, and the endocrinologist, on the other, be reconciled? It would appear that both views can not be true, provided they are mutually exclusive. If the chromosomes are alone responsible for resemblance then the endocrinologists must be deceived in their conclusion. If the hormones are alone responsible for resemblances then there must be something false in the scientific methods of the geneticist. Either of these conclusions is, however, untenable since both the students of chromosomes and of hormones have worked by the best of scientific methods so that their results are unassailable. Hence we must consider both views to be true and that the chromosomes and the hormones each have their rôle to play in the direction of development. The most tenable hypothesis of the nature of the chromosomes is indeed that they are packages of enzymes which activate the metabolic processes of the early stages of development, just as the hormones of the endocrine glands control metabolism in later stages. The hypothesis may be suggested that the chromosomes direct the early stages of development and create certain centers of chemical activity to which they hand over the business of differentiation of particular parts. Thus

the chromosomes may work indirectly in establishing certain centers of later chemical activity whose course they have determined, but in the working of whose mechanism they subsequently do not interfere. The endocrine glands of vertebrates represent perhaps a still later and highly specialized stage in the series of regulators of metabolism. In the invertebrates and in plants where such endocrine glands are unknown, it is probable that there are, nevertheless, regulating centers constituting various links in the developmental chain which starts with the fertilized egg and its chromosomes and ends with the fully formed parts and tissues. These endocrine glands and other developing controlling tissues are what the chromosomes make them.

This hypothesis receives support from the observations that have been made upon the physiology of the later stages of development, with their processes of folding of membranes, of concrescence, of disruption of parts by mechanical and histolytic processes, and the development of special tissues with their special kinds of form and substance such as are seen in the various connective tissues of the higher animals. These tissues are indeed responsive, in turn, not only to the hormones which seem so largely to control their development but also to external agents, such as pressure, gravity and radiant energy.

The science of genetics has, in the past, suffered from too narrow a point of view. The evidence of the important rôle played by the chromosomes has been so overwhelming that it has blinded us to the presence of other agencies only indirectly ruled by the chromosomes. A consideration of all the facts should enforce the view that one of the greatest fields of biology, which has been comparatively untouched, is that of the physiology of development. Embryology has indeed been studied by the morphologist. A certain beginning has been made into the field of experimental embryology; but this has been confined largely to the early stages of development. Something has been learned by transplantation experiments in later stages of the amphibia. But it remains true that the field of physiological embryology has been relatively little cultivated. The science of genetics can not be considered well established until we have some better conception of how the chromosomes do their work, of the chemical nature of the different developmental processes and the interaction of parts of the developing organism upon each other.

The appreciation of the complicated nature of development, the knowledge of the chain of developmental processes, each link of which is activated by a preceding link, helps us to understand more clearly the relation of heredity and environment. No physi-

ologist can fail to recognize that all development is under the control of agencies external to the developing center. In the earliest stages of development, indeed, the processes of differentiation seem to have a remarkable independence of environment. Even though the organism be turned inside out, as in the case of the lithium larvae of sea urchins produced by Herbst many years ago, still the spicules and other differentiating characters will be laid down in nearly normal fashion. But every student of plant genetics knows that the final form is dependent upon conditions of nutrition, temperature and the like, and students of human development are aware of the influence which the nervous system exerts upon the production of hormones. This nervous system is, of course, the organic complex which is most directly affected by external conditions and the production of hormones which has so marked an influence upon development. What is true in later stages is, no doubt, true in still earlier ones and thus one can see the basis for the conviction which has for a long time been held by thoughtful medical men that various kinds of shocks, or poisons introduced into the body, affect the development of the fetus. The striking cases of resemblance in close relatives and especially in identical twins occur where conditions of life are nearly uniform in the developmental period. Where these conditions affect differently the individuals with the same germ plasm the end result is a morphological difference. The student of genetics must take into account, therefore, chromosomes, hormones, other developmental impulses and environmental conditions if he would understand all the factors that determine development.

THE PHYSICAL BASIS OF DISEASE

X. UNSOLVED PROBLEMS IN RESEARCH MEDICINE

By THE RESEARCH WORKER
STANFORD UNIVERSITY

"COME down and spend your spring vacation in Pasadena," wrote the manufacturer. "You and the wife. Bring the kids. It will seem like old times to have children in the house once more."

"Yes, it's got me," said the manufacturer as he greeted his guests at the railway station, two weeks later. "Came to Southern California to scoff. Remain to worship. Have turned the Pittsburgh plant over to the boys. They're having the time of their lives. So'm I. Thus far it hasn't hurt profits. Now, if you young biologists will pile into the front seat. Or, am I mistaken in assuming you boys are going to be biologists when you grow up?"

"I'm goin' to be a surgeon-doctor," said the five-year-old, "not a guinea-pig doctor like Daddy."

"I go't'be a belly-doctor," said the three-year-old.

"We've not yet given up hope of making business men of both," said their mother.

2

That afternoon they drove by the new Astronomical Institute.

"That'll interest you," said the manufacturer. "Astronomical research. Has put Los Angeles on the high-brow map. Best publicity stunt in Southern California. Weighs the stars, Einstein theory and all that. Two million dollar endowment. Most expensive apparatus in the world. Single instruments costing $40,000."

"Two million for astronomical research," said the research worker. "And not a dollar in Southern California for fundamental medical and hygienic problems. Don't expect me to be enthusiastic. Modern astronomy is an intellectual luxury that should be supported only after pressing problems of human life have been solved. In ten years' time this two million may lead to acceptance or rejection of the Einstein theory. Of remotest bearing on human life. The same sum spent in fundamental medical research might yield facts giving dominion over tuberculosis and cancer. As single biological facts have already given dominion over yellow fever and diphtheria.

"There is no city in the world where fundamental medical research is more needed than Los Angeles. A million people. Fully

a third belonging to politically active, anti-medical, anti-hygienic cults. African Voodooism masquerading in the nomenclature of Christianity. Financed by predatory commercial interests. A yearly sacrifice of ten thousand human lives. If you want a publicity stunt, do something to show there is at least a nucleus of hard-headed medical intelligence in this hag-ridden burg. Not a single new fundamental medical fact from all Southern California in the entire history of the state."

"But the doctors here have patients and guinea-pigs," said the manufacturer. "What more do they want?"

"Equipment. Leisure. Competent technicians. Stimulating leaders. Do you realize medical research requires a greater range of equipment than any other research field? Greater versatility. Electrical apparatus ten times as delicate as the radio. Microscopes rivaling in accuracy the telescopes of the astronomer. Micro-photography. Chemical equipment more varied than an industrial plant. Aseptic operating rooms. Facilities for hygienic care of experimental animals. Your $40,000 instrument turned into medical equipment would barely furnish a suite of rooms for one research worker."

"But the discoveries of the past were made with simple apparatus," insisted the manufacturer.

"The four-inch telescope of the ancient astronomer was the most up-to-date instrument of his time. His discoveries were made largely because he had this wonderful new instrument, beyond the reach of his contemporaries. A Newton to-day could add nothing to fundamental astronomical knowledge with such an instrument. The time is past when a novice, a clinical microscope and a handful of test-tubes can add fundamental facts to medical science.

"Besides there is the cost of animals. Technical assistants. Dogs, five dollars apiece. Scrupulous hygienic care for months. Monkeys, twenty dollars. In the research that gave the world its present partial control of infantile paralysis, one worker alone used a thousand monkeys. A problem that could not be studied on less expensive animals. Twenty thousand guinea-pigs in the fundamental researches that gave the present partial mastery of diphtheria. No provision in Southern California for serious research of this type."

3

That evening the retired superintendent and wife dropped in for a game of bridge.

"Secretary of our local anti-vivisection society," whispered the manufacturer, as they came up the walk. "Greetings, friends. May I introduce a professional vivisector."

"Just think," said the superintendent's wife to the wife of the research worker. "This morning, when I saw your husband on the lawn with the children and the dogs, I thought him such a kind, benevolent man. And he turns out so cruel, so immoral. Cuts up living animals."

"You object to vivisection on moral grounds?" asked the research worker.

"A sin equal to murder."

"I overheard your cook gossiping with the cook across the way. At your dinner last night you served capon and lamb fries. Four cockerels and two dozen lambs vivisected for your guests. Your dog has been spayed. We drove by the Glendale Farms. Cattle dehorned. Vivisection milk for your baby. The fur you wore as you entered is 'broadtail.' Unborn lamb. Often obtained by Caesarian section. Your objection to vivisection can not be on moral grounds. There must be some underlying psychological reason."

"It's an insult to God and man," said the superintendent, "to assume that soulless brutes are so nearly like man that advances in medicine can be made by cutting up animals. That's the psychological reason. An argument you can't answer."

"And medical progress?"

"By clinical observation, accumulated experience, experiments on human volunteers."

"I was a worker in Ehrlich's laboratory at the time he was developing salvarsan, the modern treatment of syphilis. Do you know the history of salvarsan?"

"Can't say I've been interested."

"Not interested! And ten per cent. of the people of California are syphilitic. Millions spent annually for the care of criminals, insane, demented. Mainly syphilitic. Fifty million dollars subtracted from the potential annual revenue of the state. If every fruit tree in California should die, the economic loss could be fully made up by the elimination of this one disease.

"Syphilis has been studied for four hundred years by clinical and statistical methods. Medieval religio-therapy, empirical formulae, health resorts. What result? One imperfect remedy, mercury. Requiring two years of daily dosing. A twenty-five per cent. probability of cure. No experimental method of study was possible. The germ of syphilis was not known. Apparently not transferable to lower animals.

"Twenty years ago the germ was discovered. Much to the surprise of clinicians it proved to be a very delicate protozoan-like parasite. More closely related to malarial fever and sleeping sick-

ness than to ordinary bacteria. Clinicians began to wonder if some of the newer therapeutic agents, successful with other protozoan diseases, might not be more valuable than mercury. No clinician, however, had the courage to substitute these agents for mercury with his patients. It would have meant the sacrifice of a hundred human lives to have adequately tested their possibilities.

"About fifteen years ago, it was found that a very mild disease could be produced in rabbits, by special inoculation methods with syphilitic virus. That the protozoan-like germs remained alive in the rabbit's body long enough for therapeutic tests. For the first time lower animals could be substituted for human beings in therapeutic study of this disease. A wide range of new drugs was tried. An internal antiseptic found. Salvarsan. Tolerated by rabbits in sufficient doses to rid them of injected syphilis germs. Research workers were now for the first time in position to say to clinicians, 'Here is something of sufficient promise to warrant human experimentation.'

"Volunteers offered themselves to determine the safe dose for human beings. Salvarsan then substituted for mercury with hundreds of syphilitics. In sixty per cent., syphilis disappeared as by magic from their bodies. A sixty per cent. efficient drug. Replacing a twenty-five per cent efficiency of mercury. A few days' treatment, instead of the two years daily medication of the older clinicians. A result from animal experimentation carried over unchanged into human medicine."

"Salvarsan is immoral," said the superintendent's wife. "That disease was put on earth as a just punishment for sexual sin."

"An argument no biologist will attempt to answer. Biology thinks only of the thousand clean men with syphilitic wives. The ten thousand innocent women with syphilitic husbands. The hundred thousand blameless syphilitic babies. Ehrlich entered upon this research with religious fervor. 'Gain dominion over the biological world,' was the challenge he received from his conception of God. Syphilis to him, a just punishment for biological ignorance."

"But Ehrlich was a Jew," interrupted the superintendent.

"Racial antipathy is no argument against the correctness of Ehrlich's point of view."

4

"Admitting, for the sake of argument, that vivisection was of use in developing salvarsan," said the superintendent, "and remember, I'm not really admitting it—that's no excuse for further syphilization of animals."

"How about the possibility of replacing the sixty per cent. efficiency of salvarsan with an eighty per cent. efficiency. Ninety per cent. A hundred per cent. Elimination of syphilis from the civilized world. That's the dream of current vivisectors. Sufficient progress has been made during the last few years to warrant the belief this dream will eventually come true. But only after thousands of animal experiments."

"But in most medical fields vivisection is useless," insisted the superintendent.

"Many human diseases have not yet been transferred or reproduced in lower animals. These diseases can only be studied by clinical methods. The greatest handicap to this clinical study is popular objection to autopsies. If you're seeking a way to assist clinicians with these diseases, nothing would be more valuable than popular education as to the value of autopsies."

"I'd never consent to the mutilation of a friend's body," said the superintendent's wife.

"The undertaker mutilates the body. Followed by internal chemical defilement."

"What a horrid evening!" said the superintendent's wife, as she and her husband returned to their home.

"Fanatical materialist!" said the superintendent.

5

Two evenings later the manufacturer and research worker were motoring through the down town sections of Los Angeles. Fragments of oratory reached them from groups collected at street corners:

"The octopus of Wall street," shouted one speaker. "A million tentacles. Reaching into every home. How long will ye remain dormant, ye sons of toil!" . . . "Monogamic marriage is contrary to nature," declared a second. "Marriage should be where love is. To-day I may love one. To-morrow I must be free to"—

"Strong meat for sixteen-year-olds," said the manufacturer.

"Come ye halt, ye blind," implored a third. "Bring thine broken bodies. Throw physics to the dog. Only in the blood of the" . . . "Then arose that great luminary of economics, Hen-ery George. 'The unearned increment is a public asset,' he said, 'not a private' " . . . "Absolutely without pain," a voice from an arcade. "I will now extract the tooth. I take this syringe. Painless Pinto's secret anesthetic" . . .

"What's his secret?" asked the manufacturer.

"The fact that he is using the same anesthetic as every other modern dentist."

"See them in their charnel house!" shrieked a woman. "Your child's collie writhing in their grasp! With fiendish grins they plunge the red-hot irons! And chuckle as he squirms."

"How are you going to answer such a charge?" asked the manufacturer.

"We tried to answer it in our laboratory a number of years ago, by admitting anti-vivisectionists freely to the operating rooms. A group of white-gowned medical students gaining skill as anesthetists and surgeons. A careful aseptic operation on a dog. A few words as to its research purpose. Complete reversal of attitude on the part of the anti-vivisectionist. Never knew it to fail. Even had anti-vivisectionists remain as voluntary anesthetists. Anti-vivisection propaganda has practically ceased in our community."

"Cruel and unnecessary!" continued the woman. "Even admitting their argument that in the past practical hunches have come from this devil's pastime—which is a lie!—a damnable lie!—nothing more can possibly come of it."

"How about it?" asked the manufacturer.

"For every fact thus far gained by animal experiment there are a hundred embarrassing problems to be solved only by vivisection.

"Enter any hospital. The first bed, inoperable cancer. The physician almost helpless before it. One tissue stimulated to excessive growth. Penetrating and destroying surrounding parts. He knows not the cause. No drug to stop it. One single new experimental fact may give him the desired cure. Inoperable cancer! If diagnosis could only have been made in the incipient stage. A single new experimental fact may give the necessary diagnostic test."

6

"But cancer's an extreme example," said the manufacturer.

"No. Fairly typical. Another example. Tuberculosis. No single disease in which more animal experiments have been done. Few diseases in which the physician to-day is so helpless. The causative agent is known. Method of transmission fairly well understood. Fairly reliable diagnostic test. But all attempts to find a method of rendering a normal individual sufficiently resistant to tuberculosis for safe daily contact with his fellow-man have failed. A new fundamental biological fact may give the much sought anti-tuberculosis vaccine. No reliable anti-serum has been found. No drug that will free the body from the invading germs. Nevertheless in time a salvarsan for tuberculosis is a certainty. A question of continued animal experimentation."

"Always thought tuberculosis well understood," said the manufacturer.

"Cancer and tuberculosis are typical of the present limits of medical knewledge. The neurologist. Almost helpless with neurasthenia. One single new chemical fact may give complete control. The obstetrician. Almost powerless with eclampsia. Years a clinical study. Ignorant of the fundamental cause. A new biological fact needed. The military surgeon. Ten soldiers dying from shock to one killed by bullets. Rudimentary ideas as to the biological factors involved.

"See the honor with which the profession has greeted insulin. A single vivisection product. The impatience with which it awaits similar products from other glands. See the pediatricians' intense interest in experimental studies of vitamins. The surgeons' eager hope from experimental cardiac surgery. Repair the heart valves. Already applied to man. The oculists' enthusiasm over successful eye transplantations in rats. The whole medical profession. Imploring experimental science for new fundamental biological facts."

7

"And the potential research workers of Los Angeles? For you have them here. Competent men. In spite of your seventy-five per cent. of quacks, incompetents and unscrupulous. These potential workers turning to the wealth of Southern California, 'Give us equipment, leisure, skilled technicians, that we may answer the Divine challenge, the Divine command.'

"And the wealth of Los Angeles? Continues with its motors and its golf. A few mumbling, 'Ah-e-gish! Ah-e-gish! Help us, lest we perish.'"

"I'll be damned if it does," said the manufacturer. "Say, do you know what this burg can do, when it gets up on its hind legs and begins to howl? Make any other city on the footstool look like thirty cents. Gad! I'll do it! I've been hungry for a job since I quit. Start it myself. Ten thousand. Two hundred men on the same basis. Two million in three months. No. We'll make it five million. Most up-to-date building in the world. Biggest research whale in all Europe as director. And that damned African legend over the front door."

"That's the research institute I had in mind when I improvised the legend," said the research worker.

THE MEDICAL OBSERVATIONS AND PRACTICE OF LEWIS AND CLARK

By Dr. J. HOWARD BEARD

UNIVERSITY OF ILLINOIS

On January 18, 1803, President Jefferson sent a private message to Congress requesting $2,500 for a "literary pursuit" which in reality was "for the purpose of extending the external commerce of the United States." By this method, Mr. Jefferson obtained the sanction of his government to explore the interior of the continent of North America, particularly the valleys of the Missouri and Columbia rivers and their tributaries, without arousing the suspicion of nations with possible claims upon the territory to be traversed.

Mr. Jefferson selected Meriwether Lewis, his private secretary, to lead the expedition. Lewis was a graduate of a Latin school, a keen observer, a captain of the regular army, and a soldier of experience. After his appointment Lewis went to Philadelphia, where he spent some time "under the tutorage of the distinguished professors of that place."

With the approval of the president, Lewis wrote to his friend, William Clark, inviting him to share in the fatigue, dangers and honors of the expedition on equal terms. Clark accepted with enthusiasm. William Clark was a veteran of Indian wars, an expert woodsman, a man of sterling integrity and of an indomitable spirit in the presence of hardship and danger. Although he possessed great native ability, his journals show his frontier life had been too strenuous to permit his becoming a scholar.

On February 28, 1803, President Jefferson sent confidential letters to Caspar Wistar and Benjamin Rush, informing them of his having received the approval of Congress to explore a transcontinental route to the Pacific Ocean, and of the selection and qualifications of Captain Lewis, the leader of the expedition. He requested them to prepare notes of those things which they thought worthy of observation and of inquiry by the leader of the party. He advised them that Captain Lewis would call upon them at Philadelphia within two or three weeks.

Besides the two leaders, the personnel of the expedition consisted of 43 men who were frontiersmen from Kentucky and soldiers from the western garrisons. York, a negro servant of Captain Clark, accompanied his master. Captain Lewis engaged as inter-

preter Charboneau, who brought with him his Indian wife, Sacajawea.

Jefferson's Instructions to Lewis

While the principal objects of the expedition were commercial and political, Mr. Jefferson in his letter of instruction to Captain Lewis on June 20, 1803, specifically mentions a wide range of subjects worthy of special consideration and record as a means for enlarging the boundaries of knowledge. His directions pertaining to topics relating to medicine are peculiarly interesting and reflect the medical knowledge of his day.

> You will therefore endeavor to make yourself acquainted as far as diligent pursuit of your journey shall admit . . . with their (Indians) food, clothing & domestic accommodations; the diseases prevalent among them & the remedies they use; moral & physical circumstances which distinguish them from the tribes we know . . . carry with you some matter of the kine-pox; inform those of them with whom you may be of its efficacy as a preservative from the small-pox; and instruct & incourage them in the use of it. this may be especially done wherever you winter.

The fact that no physician accompanied the expedition and that both Captains Clark and Lewis practiced medicine rather systematically among the enlisted men and the Indian tribes with whom they came in contact make their journey of peculiar interest to the student of medicine. The dangers by land and by water and the length of time the members of the party were away from civilization excite his curiosity as to the methods and medicine used in the care and treatment of cases of accident and disease. The medical observations of both leaders are exceptional, but some of the "bedside notes" of Captain Lewis are so extraordinary as to do credit to a Dieulafoy or an Osler.

Clark's Questions for the Making of Observations

Having received the instructions of President Jefferson, Captain Clark transcribed them into a series of questions, the following part of which pertains to medicine and throws considerable light upon the subsequent observations of Clark and Lewis upon this subject:

Physical History and Medicine

> What is their State of Life as to longivity?
> at what age do both Sexes usially marry?
> How long do the Women usually succle their Children?
> What is the diet of their Children after they wean them?
> Is polygamy admited among them?
> What is their most general diet, manner of cooking, time and manner of eating; and how doe they preserve their provisions?

What time do they generally consume in Sleep?
What are their acute diseases?
Is rheumatism, Pluricy, or bilious fevers known among them?
& does the latter ever terminate in a vomiting of black matter?
What are their chronic diseases—are palsy, apoplexy, Epilepsy, Madness, the goiture (or Swelled Neck) and the Venereal disease known among them?
What is the mode of treating the Small pox particularly?
Have they any other disease amongst them, and what are they?
What are their remidies for their different diseases?
Are artificial discharges of blood used among them?
In what manner do they generally induce evacuation?
Do they ever use Voluntary fasting?
What is the nature of their baths, and at what time of the day do they generally use them?
at what age do their women begin and cease to menstruate?

In dealing with longevity, the age of adolescence, the character of the pulse influenced by age, sex and the time of the day, the diet of the Indians and their method of preparing it and the number of hours given to sleep, Clark's questions reveal to a considerable degree the advancement of physiology at the beginning of the nineteenth century. The nature of the baths and the time of the day at which they were taken further emphasize the interest in this subject and in hygiene.

Rheumatism receives special consideration because of its wide prevalence. Exposures, climatic changes and hardships made rheumatism a very common ailment among pioneers. Pleurisy, so-called, was well known to the public, because the same conditions were conducive to disease of the lungs and because tuberculosis was common.

Bilious fevers in 1803 were a generic term including typhoid fever, typhus fever, malaria, yellow fever, food poisoning and other illnesses with intestinal symptoms accompanied by a rise in temperature. Fevers were common and thought to be due to the exhalations of marshes, of decayed vegetable matter, to rottening timber, stagnant water, lack of drainage or bad sewerage.

Bilious fever terminating in a "vomiting of black matter" was yellow fever. This disease was attracting considerable attention, as it had killed over 4,000 people in Philadelphia in 1793. New York and Philadelphia suffered epidemics in 1798 and New York again in 1803, the year the Lewis and Clark Expedition started up the Mississippi.

Jefferson's instructions to Lewis and Clark to note the Indians' treatment of smallpox, to carry with them vaccine virus and to inform the Indians of its use shows his interest and efforts to make use of the epoch discovery of Jenner. In 1800 Jenner had sent cowpox virus to Dr. Benjamin Waterhouse of Boston. Waterhouse

sent the virus to the president, who had some 300 people vaccinated in Washington.

Unfortunately the virus given to Lewis seems to have lost its potency. In his letter to Jefferson on October 3, 1803, from Cincinnati, Lewis wrote: "I would thank you to forward me some of the Vaxcine matter, as I have a reason to believe from experiments with what I have, that it has lost it's virtue." There is no further record of Jefferson sending a second supply of virus or of it being used by either Lewis or Clark.

Venereal disease among the aborigines of America had been known since the return of Columbus to Barcelona in 1493. Its extent, incidence and origin were subjects of continued speculation and study by scientists of the eighteenth and nineteenth centuries. The prevalence of a disease of so great social significance would naturally stimulate inquiry in such scientific minds as those of Jefferson, Wistar and Rush.

Practically nothing was known of the actual cause of goiter one hundred years ago. Its exophthalmic form attracted attention wherever present and created much interest as to its nature. "Swelled neck" or simply goiter was common among the Indians and settlers in the Great Lakes Region, which fact in all probability accounts for Clark's question concerning it.

Apoplexy, epilepsy, palsy and madness are specifically mentioned in Clark's list of questions, because little was known concerning their pathology and their symptoms were so characteristic and awe-inspiring as to excite fear and horror. Rabies was common among domestic animals and not very infrequent among the early pioneers. It caused so much destruction among wolves that many observers believed it did more to exterminate them than the guns of our forefathers or the advancement of civilization.

The Medicine Chest

Lewis and Clark started on their trip during the drastic era of medicine. They lived during the period when the great attack upon disease was directed through the emunctories. In their day, the most powerful weapons in the armamentarium of the physician were the lancet and the eliminant. Purgation, sweating, salivation, blistering and bleeding were the shock troops hurled against entrenched disease. They frequently cured but never failed to impress the patient.

The following bill, made by Purveyor Israel Wheelen "for the use of M. Lewis Esquire on his tour up the Mississippi and supplied by his order," gives a clear conception of the therapeutics of the time and is also suggestive of the medical emergencies anticipated by the leaders of the expedition.

Bill of Gillapsy & Strong for Medicine

Israel Wheelen Purveyor Bought of Gillapsy & Strong

the following articles for the use of M. Lewis Esquire on his tour up the Missisipi River, and supplied by his Order:—Viz

15 lb.	Pulv. Cort. Peru	$30.00	4 oz.	Laudanum	.50
½ lb.	" Jalap	.67	2 lb.	Ung. Basilic Flav., 50	1.00
½ lb.	" Rhei (Rhubarb)	1.00	1 lb.	" e lap Calimin .50	.50
4 oz.	" Ipecacuan	1.25	1 lb.	" Epispastric	1.00
2 lb.	" Crem. Tart.	.67	1 lb.	" Mercuriale	1.25
2 oz.	Gum Camphor	.40	1.	Emplast. Diach. S.	.50
1 lb.	" Assafoetid	1.00	1.	Set Pocket Insts. small	9.50
½ lb.	" Opii Turk. opt	2.50	1.	" Teeth " "	2.25
¼ lb.	" Tragacanth	.37	1.	Clyster Syringe	2.75
6 lb.	Sal Glauber 10	.60	4.	Penis do.	1.00
2 lb.	" Nitri 33½	.67	3.	Best Lancets .80	2.40
2 lb.	Copperas	.10	1.	Tourniquet	3.50
6 oz.	Sacchar. Saturn. opt.	.37	2	oz. Patent Lint	.25
4 oz.	Calomel	.75	50	doz. Bilious Pills to Order of B. Rush 10	5.00
1 oz.	Tartar Emetic	.10	6	Tin Canisters 25	1.50
4 oz.	Vitriol Alb.	.12	3	8 oz. Gd. Stopd. bottles	1.20
½ lb.	Columbo Rad.	1.00	5	4 oz. Tinctures do	1.85
¼ lb.	Elix. Vitriol	.25	6	4 oz. Salt Mo.	2.22
¼ lb.	Ess. Menth. pip.	.50	1	Walnut Chest	4.50
¼ lb.	Bals. Copaiboe	.37	1	Pine do.	1.20
¼ lb.	" Traumat.	.50		Porterage	.30
2 oz.	Magnesia	.20			
¼ lb.	Indian Ink	1.50			
2 oz.	Gum Elastic	.37			$90.69
2 oz.	Nutmegs	.75			
2 oz.	Cloves	.31			
4 oz.	Cinnamon	.20			
		$46.52			

The above bill shows the medicine chest contained among other things fifteen pounds of febrifuge, approximately 1,500 doses of purgative, 1,100 of emetic and 3,500 of diaphoretic. Blistering was provided for by one pound of epispastric or cantharidis ointment; salivation by four ounces of calomel and one pound of mercury ointment. Three of the best lancets were included for bleeding. In addition to the drugs provided by the purveyor other records reveal that in the medicine chest there were one pound of the flour of sulphur, eight ounces of borax, two sticks of simple diachylon and three extra lancets. Some of the men also carried their favorite medicines. Captain Lewis seems to have had a generous supply of Scott's Pills.

Therapeutics

Both Captains Lewis and Clark showed great resourcefulness in bringing relief to the men under their command when sick. They

drew upon the medical supplies when needed, but if those were not available or the medicines did not seem to produce the desired result, they did not hesitate to make use of the plants along the route or to accept the suggestions of the other members of their party.

Gastro-enteritis

Gastritis and enteritis were very common among the party, due to the diet, exposure and fatigue. Meat composed the greater part of their food and was often neither properly preserved nor sufficiently fresh for use. Polluted water, water impregnated with salts of a laxative action and roots eaten containing a purgative principle produced disorders of the stomach and intestines. Fatigue before and after meals and the method of preparing such foods as could be obtained contributed to the discomfort of the party.

The usual treatment of gastritis was a dose of Glauber salts. In the more severe cases 35 drops of laudanum was administered after the saline. When Lewis became suddenly ill while out of the reach of his medicine chest he was not averse to try an experiment with "some simples" that "first struck his attention."

> I was taken with such violent pain in my intestines that I was unable to partake of the feast of marrow bones. my pain still increased and towards evening was attended with a high fever; finding myself unable to march, I determined to prepare a camp of some willow boughs and remain all night. Having brought no medicine with me, I resolved to try an experiment with some simples; and the Choke cherry which grew abundantly in the bottom first struck my attention; I directed a parcel of small twigs to be geathered, striped of their leaves, cut into pieces of about two inches in length and boiled in water until a strong black decoction of an astringent bitter taste was produced; at sunset I took a point (pint) of this decoction and about an hour after repeated the doze, by ten in the evening I was entirely relieved from pain and in fact of every symptom of the disorder forsook me; my fever abated, a gentle perspiration was produced and I had a comfortable and refreshing nights rest. This morning I felt myself quite revived, took another portion of my decoction and set out at sunrise.

Emesis was also employed in certain cases of gastric disorder, but the "doctors" were not always in entire agreement as to the best emetic to use. Their difference of opinion had little effect upon the prompt recovery of the negro York, who had food poisoning. Clark observes, "my man York sick; I give him a dost of Tartar." Lewis states, "Capt. Clarks black man York is very unwell today and he gave him a doze of tartar emetic which operated very well and he was much better in the evening. this is a description of medicine that I never have recourse to in my practice except in cases of intermittent fever."

Lewis was no less successful than Clark in obtaining prompt relief for his sick associates.

I found Wiser very ill with a fit of the cholic. I sent Sergt. Ordway who had remained with him for some water and gave him a dose of the essence of Peppermint and laudinum which in the course of half an hour so far recovered him that he was enabled to ride my horse.

Clark was in no sense a drug nihilist. In treatment he was energetic, thorough and drastic when his patients did not show prompt improvement. "Capt. Lewis still very unwell, Several men taken sick on the way down, I administered Salts Pils Galip (jalap) Tartar emetic etc. I feel unwell this evening."

Venesection

Blood-letting was almost considered a panacea during the first quarter of the 19th century. It was highly recommended by the great majority of physicians and many laymen were loud in its praise. Before the patient was bled he was given an emetic, purged, salivated with mercury and often blistered and sweated. The purpose of this drastic elimination was to abstract excitement, congestion and inflammation from the vital organs. Theoretically, such complete depletion left nothing upon which the disease could work. Therefore, the patient had an opportunity to recover.

With Captain Clark venesection was a sovereign remedy.

one man was taken violently Bad with the plurisie, Bleed & apply those remedies Common to that disorder. I bled the man with the plurisy today (next day) & swet him. The sick man yesterday is getting well. Drewyer was taken last night with a violent pain in his side. I bled him. This evening (next day) Drewyer went in quest of his traps and took an otter. Scheagagwea, our Indian woman verry sick. I blead her.

Lewis was more conservative in the practice of blood-letting but no less versatile and prompt in using it, once he had decided it was desirable.

Whitehouse one of them (the party) much heated and fatigued on his arrival drank a very hearty draught of water and was almost taken instantly extremely ill. his pulse were full and I therefore bled him plentifully from which he felt great relief. I had no other instrument with which to perform this operation, but my pen knife, however it answered very well.

Rheumatism

Coldness, dampness and hardship caused much muscle soreness, sprains, strains and arthritis among the members of the party. Sergeant Gass gives a clear account of the conditions experienced by the men that were conducive to this affection.

Some of the men are complaining of rheumatic pains, which are to be expected from the wet and cold we suffered last winter; during which, from the 4th of November 1805, to the 25th of March 1806, there were not more than twelve days in which it did not rain and of these but six were clear.

Captain Clark describes attacks of the disease among his men, in an Indian girl, and in himself. His skill in the treatment of rheumatism was of such high order as to be worthy of a fee of the best trained specialists. "We received a second horse for medicine and prescription to a little girl with the rheumatism whome I bathed in worm water, and anointed her a little with balsam capivia."

Captain Lewis, by using hot applications in treating "rheumatism," anticipated modern methods.

Last night at 1 oClock I was violently and Suddenly attacked with the Rheumatism in the neck which was so violent I could not move. Capt. Lewis applied a hot Stone Raped in flannel, which gave me some temporary ease. . . . A cloudy morning (next day) Some Snow. Set out early. . . . R. Fields with the Rhumitism in his neck, P Crussat with the Same complaint in his Legs,—the party otherwise well, as to myself I feel but slight Simptoms of that disordr at this time (three days later). . . . John Shields sick today with the rheumatism.

Colds and Influenza

The exposure of the men to wet and to chill produced an epidemic of common colds. In February, 1806, Clark described a disease with which his men were affected that would seem to warrant the conclusion that the influenza which had been epidemic in eastern parts of the United States had succeeded in locating his expedition. Many of the men were ill. "The general complaint appears to be bad colds and fevers, with a violent pain in the head and back, something I believe of the influenza."

The malady attacked the men suddenly, caused great prostration, but was quickly followed by improvement, except in the cases of Willard and Bratton. Private Bratton evidently suffered a complication and ill for a long time until given rather strenuous sweat baths. Convalescence was slow, due largely to inadequate diet. The failure to gain strength may have also been caused, in a measure, by prostration. "The diet of the sick is so inferior that they recover their strength but slowly. none of them are now sick but all in a state of convalescence, with keen appetites and nothing to eat except lean Elk meat."

On February 16, Lewis notes that:

Bratton is still very weak and complains of a pain in the lower part of the back when he moves which I suppose proceeds from dability. I gave him barks. Gibson's fever still continues obstenate tho not very high; I gave him a dose of Dr. Rush's which in many instances I have found extreemly efficacious in fevers which are in any measure caused by the presence of boil. the nitre has produced a profuse perspiration this evening and the pills operated late at night his fever after which abated almost entirely and he had a good night's rest.

Continue the barks with Bratton, and commenced them with Gibson his fever being sufficiently low this morning to permit the uce of them. I therefore think that there is no further danger of his recovery.

Gave Willard and bratton each a doze of Scotts pills; on the former they operated and on the latter they did not Gibson still continues the barks three times a day and is on the recovery fast.

Bratton is much worse today, he complains of a violent pain in the small of his back and is unable in consequence to set up. we gave him one of our flanel shirts, applied a bandage of flannel to the part and bathed and rubed it well with some vollatile linniment which I prepared with sperits of wine, camphor, castile soap, and a little laudanum. he felt better in the evening.

Two weeks later the men were still sick and Bratton and Willard are causing Clark uneasiness.

Maney of our men are still complaining of being unwell; Bratton and Willard remain weak principally I believe for the want of proper food. I expect when we get under way that we shall be much more healthy. it has always had that effect on us heretofore.

Our sick men Willard and Bratton do not seem to recover; the former was taken with a violent pain in his leg and thye last night. Bratton is now so much reduced that I am somewhat uneasy with respect to his recovery; the pain of which he complains most seems to be settled in the small of his back and remains obstinate. I believe it is the rheumatism with which they are both affected.

A Russian Bath in the Wilderness

Three months after the beginning of his attack Bratton's ailment had resisted every remedy that Clark and Lewis could devise. John Shields, the gunsmith of the expedition, recommended sweating with the most happy results.

William Bratton still continues very unwell; he eats heartily digests his food (very) well, and has recovered his flesh almost perfectly yet is so weak in the loins that he is scarcely able to walk, nor can he set upright but with the greatest pain. We have tried every remidy which our ingenuity could devise, or with which our stock of medicines furnished us, without effect. John Shields observed that he had seen men in similar situation restored by violent sweats. Bratton requested that he might be sweated in the manner proposed by Shields to which we consented. Shields sunk a circular hole of 3 feet diameter and four feet deep in the earth. he kindled a large fire in the hole and heated well, after which the fire was taken out a seat placed in the center of the hole for the patient with a board at bottom for his feet to rest on; some hoops of willow poles were bent in an arch crossing each other over the hole, on these several blankets were thrown forming a secure and thick orning of about 3 feet high. the patient being striped naked was seated under this orning in the hole and the blankets well secured on every side. the patient was furnished with a vessell of water which he sprinkled on the bottom and sides of the hole and by that means creates as much steam or vapor as he could possibly bear, in this situation he was kept about 20 minutes after which he was taken out and suddenly plunged into cold water twise and was then immediately returned to the sweat hole where he was continued three quarters

of an hour longer then taken out covered up in several blankets and suffered to cool gradually. during the time of his being in the sweat hole, he drank copious draughts of a strong tea of horse mint. Sheilds says that he had previously seen the tea of Sinneca snake root (The Seneca snake-root) used in the stead of the mint which was now employed for the want of the other which is not to be found in this country. the experiment was made yesterday; Bratton feels himself very much better and is walking about today and says he is nearly free from pain.

A week after having his semi-Russian bath, Bratton "has so far recovered that we can well consider him an invalid no longer. he has had a tedious illness which he boar with much fortitude and firmness." He apparently endured his treatment with equal resignation.

The Tragic Story of Smallpox

A stellar rôle in the great tragedy of the disappearance of the American Indian was played by variola. It was more deadly to the natives than the bullets of the paleface, more unrelenting than his insatiable desire for land. It destroyed whole villages, drove remnants of tribes to desperation, and so weakened many Indian nations that they were easily conquered by their enemies. The following extracts from Clark's Journal cover a three-year period of travel and therefore show that smallpox had swept through the Indian villages from the mouth of the Missouri River, over the Great Divide, and down the valley of the Columbia to the Pacific Ocean.

The men sent to the Mahar Town last evening . . . returned and informed us that they Could not find the Indians, nor any fresh Sign those people have not returned from their Buffalow hunt. Those people haveing no houses no Corn or anything more than the graves of their ancestors to attach them to the old Village, Continue in purseute of the Buffalow longer than others who has greater attachments to their native village. The ravages of the Small Pox which Swept off (about 4 years ago) 400 men and Womin and children in perpopotion has reduced this nation not exceeding 300 men and left to the insults of their weaker neighbors, which before was glad to be on friendly turms with them.

I am told when this fatal malady was among them they Carried their franzey to verry extraordinary length, not only of burning their Village but they put their wives and children to Death with a view of their going together to some better Countrey. . . . The cause or way those people took the Small Pox is uncertain, the most Probable, from Some other nation by means of a war party.

This nation (Clotsop) is the remains of a large nation destroyed by the Smallpox or Some other disease which those people were not acquainted with, they Speak the same language of the Chinnooks and resemble them in every respect except that of stealing, which we have not cought them at as yet.

I have endeavored to obtain from those people the situation of their nation, (Shah-ha-la), if scattered or what had become of the natives who must

have peopled this great town. an old man who appeared of some note among them and father to my guide brought forward a woman who was badly marked with Small pox and made signs that they all died with the disorder which marked her face, and which she was very near dieing with when a girl. from the age of this woman this Distructive disorder I judge must have been 28 or 30 years past, and about the time the Clatsops inform us that this disorder raged in their towns and distroyed their nation.

Lewis's single comment on the subject of smallpox is in confirmation of those of Clark as to the devastation of variola among the Clatsops, who lived near the mouth of the Columbia River, where the expedition wintered in 1805–1806.

The small pox has destroyed a great number of the natives in this quarter. it prevailed about 4 years since among the Clatsops and destroyed several hundred of them, four of their chiefs fell victyms to its ravages. those Clatsops are deposited in their canoes on the bay a few miles below us. I think the late ravages of the smallpox may well account for the number of remains of vilages which we find deserted on the river and Sea coast in this quarter.

Social Disease

Lewis repeatedly observed the presence of venereal disease and its terrible complications among the Indians. Their method of treatment in general was ineffective, and the scourge once acquired raged almost without control. Some of the enlisted men of the party of the expedition became infected and gave Lewis an opportunity to exhibit his skill as a syphilologist. As mercury was the chief specific of the day and extolled by Dr. Rush as the "Samson of the Materia Medica," Lewis gave this drug every opportunity to destroy this Philistine of the race. "I cured him as I did G. . . . last winter by the use of murcury."

I was anxious to learn whether these people (Shoshone Indians) had the venerial, and made the inquiry through the interpreter and his wife; the information was that they sometime had it but I could not learn their remedy; they most usually die with its effects. this reason is strong proof that these disorders (Neisser infection and Lues) are native disorders of America. tho' these people have suffered much by the small pox which is known to be imported and perhaps those other disorders might have been contracted from other Indian tribes who by a round of communications might have obtained from the Europeans since it was introduced into that quarter of the globe. but so much detached on the other hand from all communication with the whites that I think it most probable that those disorders are original with them.

I cannot learn that the Indians have any simples which are sovereign specifics in the cure of this disease; and indeed I doubt very much whether any of them have any means of effecting a perfect cure. When once this disorder is contracted by them it continues with them during life; but always ends in decrepitude, death, of premature old age; tho' from the use of certain simples together with their diet, they support this disorder with but little inconvenience for many years, and even enjoy a tolerable share of health.

OBSTETRICS AND GYNECOLOGY

It was vital to the success of the expedition that horses should be provided by the Snake Indians for the party to make portage from the Missouri to the Columbia River. To insure a friendly negotiation with the Snakes, Lewis took with him Sacajawea, a Shoshone captive, the purchased wife of Charboneau, his interpreter. She was the only woman permitted to accompany the expedition, and it was her presence that caused Lewis to record his observation upon the pharmacological effect of the rattle of the rattle snake in parturition.

About five Oclock this evening Sacajawea was delivered of a fine boy. This was the first child which this woman had boarn, and as is common in such cases her labor was tedious. Mr. Jessome informed me that he had freequently administered a small portion of the rattle of the rattle snake, which he assured me had never failed to produce the desired effect, that of hastening the birth of the child; having the rattle of a snake by me I gave it to him and he administered two rings of it to the woman broken in small pieces and added to a small quantity of water. She had not taken it more than ten minutes before she brought forth, perhaps this remedy may be worthy of future experiments, but I must confess that I want faith as to its efficacy.

Lewis gives the following comment on the ease of parturition among the native women.

It appears to me that the facility and ease with which the women of the aborigines of North America bring fourth their children is reather a gift of nature than depending as some have supposed on the habitude of carrying heavy burthens on their backs while in the state of pregnacy. if a pure and dry air, an elivated and cold country is unfavorable to childbirth, we might expect every difficult incident to that operation of nature in this part of the continent; again as the Snake Indians possess an abundance of horses, their women are seldom compelled like those in other parts of the continent to carry burthens on their backs, yet they have their children with equal convenience, and it is a rare occurrence for any of them to experience difficulty in childbirth. I have been several times informed by those who were conversent with the fact, that the Indian women who are pregnant by white men experience more difficulty in childbirth than when pregnant by an Indian. if this is true it would go far in support of the opinion I have advanced.

Both Clark and Lewis recorded the custom among the Indians of periodic isolation of their women somewhat similar to the practice of Biblical times. In this regard Clark records:

This man has a daughter who is not permitted to acoiate with the family but sleeps at a distance from her father's camp, and when traveling follows at some distance behind. in this state I am informed that the female is not permited to eat, nor to touch any article of culinary nature or many occupation. . . .

At all these lodges of the Chopunnish I observe and appendage of a small lodg with one fire which seems to be the retreat of their women, the men

are not permitted to approach this lodge within a certain distance and if they have anything to convey to the occupants of this little hospital they stand at a distance of 50 or 60 paces and throw it towards them as far as they can and retire. (Lewis)

The Forest Clinic

Clark and Lewis practiced medicine among the Indians, Clark actually holding clinics, and treating as many as forty patients within a few hours. He became the favorite physician and enjoyed an enviable reputation among them. Both he and Lewis seemed to have been endowed with that broad human sympathy, keen sense of responsibility, understanding and integrity that are the best traditions of the true followers of Hippocrates.

Captain Clark appreciated the value of the mental element in successful treatment. He used the methods and the medicine likely to produce a favorable impression upon the minds of his patients. Accordingly, his prestige as a physician steadily increased among the Indians.

Capt. C. (with much ceremony washed & rubed) gave an indian man some volatile liniment to rub his knee and thye for a pain of which he complained. the fellow soon after recovered and has never ceased to extol the virtues of our medicines and the skill of my friend Capt. Clark who is their favorite phisician and has already received many applications.

Clark informs us that

After brekfast I began to administer eye water and in a fiew minuts had near 40 applicants with sore eyes, and many others with other complaints most common Rhumatic disorders and weaknesses in the back and loins perticularly the womin. some simple cooling medicenes to the disabled Chief, to several women with rhumatic effections & a man who had a swelled hip &c. . . .

Thompson, one of the enlisted men, returned from the village accompanyed by a train of invalides consisting of 4 men 8 women and a child. eye water was administered to all; to two of the women cathartics were given, to a third who appeared much dejected and who from their account of her disease we supposed it to be histerical, we gave thirty drops of laudanum. the several parts of the others where the rheumatic pains were seated were well rubed with a volitile linniment. All of these poor wretches thought themselves much benefited, and all returned to their village well satisfyed. . . .

All tribes which I have passed on these waters (Columbia River) who live on fish maney of different sectes who have lost their teeth about middle age. Some have their teeth worn to the gums, perticelarly those of the upper jaw, and the tribes generally have bad teeth, the cause of it I can not account for, sand attached to the roots & the method they have of useing the dried Salmon is mearly worming it and eating the rine & scales with the flesh of the fish, no doubt contributes to it.

Lewis gives a striking description of two of their clinics that they held in the spring of 1806:

They (the Wallahwallah Indians) brought several diseased persons to us for whom they requested some medical aid. one had his knee contracted by the rheumatism, another with a broken arm &c. to all of which we administered. Ulsers and irruptions of the skin on various parts of the body are also common diseases among them. . . .

Many of the natives apply to us for medical aid which we gave them cheerfully so far as our skill and store of medicine would enable us. schrofela, ulsers, rheumatism, soar eyes and the lost of the uce of their limbs are the most common cases among them. the latter case is not very common but we have seen three instances of it among the Chopunnish.

Lewis the Clinician

Sacajawea became very ill on June 10, 1805, while Lewis was away from camp with a small party making observations. On the appearance of her symptoms Clark bled her, and again on the following day. On the fourth day of her illness he administered salts and applied poultices of Peruvian bark and laudanum. She grew steadily worse, refused medicine and her condition became so alarming that her husband requested Captain Clark to have the party turn back with her. At the height of her illness Captain Lewis arrived at camp on June 16 and made the following notes of her condition:

About 2 p. m. I reached the camp, found the Indian woman extreemly ill and much reduced by her indisposition. . . . two dozes of barks and opium which I had given her since my arrival had produced an alteration in her pulse for the better; they were now much fuller and more regular. I caused her to drink the mineral water altogether (from sulphur springs). when I first came down her pulse were scarcely perceptible, very quick, frequently irregular, and attended with strong nervous symptoms, that of twitching of the fingers and leaders of the arm; now the pulse had become regular much fuller and a gentle perspiration had taken place; the nervous symptoms have also in a great measure abated, and she feels herself much freer from pain. she complains principally of the lower region of the abdomen, I therefore continued the cataplasms of barks and laudanum which had been previously used by my friend Capt. Clark. . . .

The Indian woman much better today (June 17); I have still continued the same course of medicine; she is free from pain clear of fever, her pulse regular, and eats heartily as I am willing to permit her of broiled buffaloe well seasoned with pepper and salt and rich soope of the same meat; I think therefore that there is every rational hope of her recovery. . . .

The Indian woman is recovering fast, she set up the greater part of the day (June 18), and walked out for the first time since she arrived here; she eats heartily and is free from fever or pain. I continue same course of medicine and regimen except that I added one doze of 15 drops of the oil of vitriol today about noon. . . .

American medicine lost a great leader when Meriwether Lewis responded to the urge of adventure instead of to the wooings of Panaciea, the daughter of Aesculapius. His natural gifts, if

trained, would have undoubtedly qualified him as a most worthy successor of Benjamin Rush. His rare powers of observation, his wide information and his capacity to recognize and to differentiate the various symptoms of disease would have made him one of the great clinicians of his day.

A Chief of considerable note at this place has been for three years incapable of moving a single limb but lies like a corps in whatever position he is placed, yet he eats heartily, digests his food perfectly, in short were it not that he appears a little pale from having lain so long in the shade he might well be taken for a man in good health. As he complains of no pain in any particular part we conceive it can not be the rheumatism, nor do we suppose that it can be a parelitic attack or his limbs would have been more deminished. we have supposed that it was some disorder which owed its origine to a diet of particular roots, perhaps, and such as we have never before witnessed. . . .

While at the village of the "broken arm" we had recommended a diet of fish or flesh for this man and a cold bath every morning. we had also given him a few doses of creem of tartar and flour of sulphur to be repeated every third day. this poor wretch thinks that he feels himself somewhat better but to me their appears no visible alteration. we gave him a few drops of Laudanum, and a little portable soup. . . .

We caused a sweat to be prepared for the chief in the same manner in which Bratton had been sweated, this we attempted but were unable to succeed, as he was unable to set up or be supported in the place. we informed the indians that we knew of no relief for him except sweating him in their sweat houses and giving him plenty of the tea of the horse mint which we shewed them. and that this probably would not succeed as he had been so long in his present situation. I am confident that this would be an excellent subject for electricity and much regret that I have not in my power to supply it. . . .

the indians were so anxious that the sick Cheif be sweated under our inspection that they requested we would make a second attempt today, (May 27, 1806), accordingly the hole was somewhat enlarged and his father went in the hole with him and sustained him in a proper position during the operation; we could not make him sweat as copiously as we wished. after the operation he complained of considerable pain, we gave him 30 drops of laudanum which soon composed him and he rested very well. . . .

The sick Cheif is much better this morning (May 28, 1806) he can use his hands and arms and seems much pleased with the prospect of recovering. he says he feels much better that he has for a great many months. the Chief has much more use of his hands and arms. he washed his hands and arms. he washed his face himself today (May 29, 1806) which he has been unable to do previously for more than twelve months.

We gave the Chief a severe sweat today (May 30, 1806), shortly after which he could move one of his legs and thys and work his toes pretty well, the other leg he can move a little; his fingers and arms seem almost entirely restored. he seems highly delighted with his recovery.

We gave the Indian Cheif another sweat today (June 5, 1806), continuing it as long as he could bear it, in the evening he was very languid but still continued to improve in the use of his limbs. The sick Cheif is fast on the recovery (Jun. 8, 1806), he can bear his weight on his legs, and has acquired a considerable portion of strength.

The acute illness of the interpreter's child offered Lewis the opportunity to explore the field of pediatrics. He entered it with the same confidence that had taken him over the Continental Divide and had found favor for him in negotiation with the Indians. He exhibited the skill and resourcefulness that was ever his custom, and to which failure was foreign. His keenness of observation, attention to details, and ability to make the most of the medical supplies available, sustained nature until recovery was assured.

Charbono's Child is very ill this evening; he is cuting teeth, and for several days past has had a violent lax which having suddenly stoped he was attacked with a high fever and his neck and throat are much swollen this evening. We gave him a doze of cream of tartar and flour of sulphur and applyed a poultice of boiled onions to his neck as warm as he could bear it. . . .

The cream of tartar and sulpher operated several times on the child in the course of the last night, he is considerably better this morning, tho' the swelling of the neck has abated but little; we still apply poltices of onions which we renew frequently in the course of the day and night. The child was very restless last night, (twenty-four hours later), its jaw and the back of its neck are much more swollen than they were yesterday tho' his fever had abated considerably. we gave it a dose of creem of tartar and employed a fresh poultice of onions. . . .

The Child is more unwell than yesterday (third day of illness). we gave it a doze of creem of tartar which did not operate, we therefore gave it a clyster in the evening. The clyster given the child last evening operated very well. It is clear of fever and much better this evening, the swelling is considerably abated this evening and it appears as if it would pass off without coming to a head. we still continue fresh poltices of onions to the swolen part. . . .

Charbono's son is much better today (fifth day of illness), tho' the swelling on the side of the neck I believe will terminate in an ugly imposthume a little below the ear. The child is also better (sixth day of illness), he is free of fever the imposthume is not so large but seems to be advancing to maturity. The child is also on the recovery (one week after onset of disease). . . .

Clark, the Surgeon

Lewis practiced surgery only in emergencies; it was Clark's specialty. He had to care for infections, dislocations, fractures, gunshot wounds and many other painful injuries suffered by the men under his command. The members of the party acquired numerous abscesses and boils which were due to slight abrasions of the skin to which they were always exposed, and to insect bites. When the men visited Indian lodges they often came away infested with fleas. Mosquitoes were so numerous as to provide both a means for infection and an explanation for Captain Clark's rare poor marksmanship. "The Musquetors were so numerous that I could not keep them off my gun long enough to take sight and by that means Missed." Lewis ascribed the boils to the muddiness

of the river water, but noted that the general health of the party was excellent. His treatment of them consisted of poultices of Indian meal or elm bark. In rare instances, he employed the lance.

Bruises, cuts and lacerations were numerous among men subjected to such hardships.

> Hall had his foot and ankle much injured yesterday by the fall of a large stick of timber; the bones were fortunately not broken and I expect he will again be able to walk shortly. Most of the party complain of their feet and legs being very sore. it is no doubt caused by walking over rough stone and deep sand after being accustomed to a soft soil. My legs and feet give me much pain. I bathed them in cold water from which I experienced considerable relief. . . .
>
> Potts cut one of the large veins on the inner side of the leg with one of the large knives; I found much difficulty in stoping the blood which I could not effect untill I applyed a tight bandage with a little cushon of wood and tow on the vein below the wound. [Four days later] Pott's legg is inflamed and very painfull to him. We apply a poltice of the roots of Cows, [Lomatium]. . . .
>
> Pott's legg which has been much swolen and inflamed for several days is much better this evening and gives him but little pain. we applyed the pounded roots and leaves of the wild ginger (Asarum caudatum) from which he found great relief. . . . Willard had cut his knee very badly with his tommahawk. . . . Wiser had cut his leg, badly with a knife and was unable in consequence to work. Shannon cut his foot with the ads in working at the perogue. . . .
>
> Gibson in attempting to mount his horse after shooting a deer this evening fell on a Snag and sent it nearly two inches into the Muskeler part of his thy. he informs me this snag was about 1 inch in diameter burnt at the end. this is a very bad wound and pains him exceedingly. I dressed the wound. he slept but very little last night and complains of great pain in his Knee and hip as well as his thy. . . . halted to let Gibson rest. his leg become So numed from remaining in one position, as to render it So Painful that he could not set on the horse after rideing about 2 hours and a half.

Two days later Gibson's wound is beginning to heal and Clark is hopeful "that it will get well in time for him to accompany Sergeant Pryor with the horses to the Mandans."

Clark had his surgical skill put to the test when Sergeant Pryor put his shoulder out of place. He made four attempts before he could replace it. (About a year later the shoulder was dislocated again while the sergeant was carrying meat.) Gibson also suffered a subluxation of his shoulder but the dislocation was promptly reduced.

The most dangerous injury received by any member of the expedition was when (August 10, 1806) Crusatte, a member of the party, mistook Captain Lewis for an elk and shot him through the thigh with a rifle. Although seriously injured, Lewis made his way back to the party and with the assistance of Sergeant Gass took off his clothes and dressed his own wounds, "introducing tents of patent

lint into the ball holes." . . . The pain he experienced "excited a high fever" and he "had a very uncomfortable night." "My wounds felt very stiff and soar this morning, but gave me no considerable pain. there was much less inflamation than I had reason to apprehend there would be. I had last evening applyed a poltice of peruvian barks."

Clark, who had been separated from Lewis, joined the party several days after Lewis had been shot and took charge of the treatment of his injured friend. By August 19 he was able to report: "Captain Lewis'es wounds are healing very fast, I am much in hope of his being able to walk in 8 or 10 days." Three days later Lewis had walked a little for the first time, and Clark "discontinued the tent in the hole the ball came out."

On September 9, Clark noted: "My worthy friend Capt. Lewis has entirely recovered his wounds are healed up and he can walk and even nearly run as well as he ever could."

Clark treated an Indian "who had his arm broke and had it loosely bound in a piece of leather without anything to support it."

> He dressed the arm which was broken short above the wrist, supported it with broad sticks to keep it in place, put it in a sling and furnished him with some lint bandages &c to Dress it in the future. . . .
>
> A chief whose wife had an absess formed on the small part of her back promised a horse in the morning provided we would administer to her, accordingly Capt. Clark opened the absess introduced a tent and dressed it with basilicon. I dressed the woman again this morning who declared that she had rested better last night than she had since she had been sick.

The Eye Dispensary and Defective Vision

Defective vision and blindness seem to have pursued the Indians with Achillean relentlessness. Lewis states "soar eyes seem to be a universal complaint among these people" and Clark, "I began to administer eye water and in a few minutes had nearly 40 applicants with sore eyes." The true source of their eye affliction is obscured by a combination of circumstances to which they were exposed conducive to impairment of sight, by the prevalence of disease among them whose complication was inflammation of the eyes and consequent blindness and by the ignorance of successful methods of treatment.

Lewis reports the presence of Neisserian infection and lues among many of the tribes of Indians in the country through which he passed. Ophthalmia neonatorum must have produced its quota of blindness. As syphilis was common among them and was permitted to develop practically without treatment, luetic inflammations and degeneration of the eye were undoubtedly factors in the production of the great impairment of sight recorded by Lewis and Clark.

It is probably correct to assume that trachoma was one of the major causes of the great destruction of vision and wide prevalence of sore eyes among them. While trachoma is essentially an imported disease, it is said to be "as old as the Nile, the simoon, and the desert." Other diseases of such venerable age and power of transmission reached the shores of America and followed the war paths of the Indian into the interior of the continent long before President Jefferson became interested in his "literary pursuit."

It has been comparatively recently that public health officials have obtained some conception of the extent of the prevalence of trachoma in the United States. A survey by the Public Health Service shows the disease exists more or less throughout the country. Indians were found to be almost universally infected and on some reservations 90 per cent had trachoma. It is now known that the disease has been endemic in the Appalachian Mountain region for years.

The severe periodic restrictions in diet practiced by certain tribes of Indians in the region of the Columbia-Missouri Divide due to seasonal scarcity of game and to the fear of their enemies may have caused deficiency of nutrition sufficient to produce inflammations of the eye. Where tribes were compelled to exist on a few dry roots for a considerable length of time the lack of sufficient fat soluble, vitamine A or a very low protein diet, combined with infection, may have brought about disease of the eye similar to xerophthalmia.

Further evidence of ill health among the Indians due to malnutrition is presented in the person of the moribund chief who was cured by the substitution of a diet of fish and flesh for that of roots, a cold bath, several doses of the flour of sulphur and sweating. Indians whose diet was largely restricted to roots also had very poor teeth. The latter condition may in part have been due to eating of the roots without the entire removal of the sand.

While Lewis was unfamiliar with vitamines, he was too experienced an observer not to note diseases in the presence of inadequate diet and not to suspect a cause and effect relationship. "I suspect that the confinement to a diet of roots may give rise to all of these disorders, (scrofula, ulcers, loss of the use of the limbs) except rheumatism and sore eyes, and to the latter of these, the state of debility incident to a vegetable diet may immeasurably contribute."

Such physical factors as intense light, foreign bodies, smoke and exposure to wind and dust were important factors in causing inflammation of the eye and impairment of sight among the Indians. Clark in one of his visits to an Indian lodge states, "the Smoke is exceedingly disagreeable and painfull to my eyes." He has also

written his opinion as to the effect of their occupation upon their vision.

I observed an Indian woman who visited us yesterday blind in one eye, and a man who was nearly blind in both eyes. The lost of sight I have observed to be more common among all the nations inhabiting this river (Columbia) than among any people I have ever observed. they have almost invariably sore eyes at all stages of life. the loss of an eye is very common among them. blindness in persons of middle age is by no means uncommon, and it is almost invariable a concammitant of old age. I know not to what cause to attribute this prevalent deficiency of the eye except it be their exposure to the reflection of the sun on the water to which they are constantly exposed in the occupation of fishing. & the snows dureing the winter Seasons in the open countrey where the eye has no rest. . . .

A very singular disorder is taking place amongst our party that of the sore eyes. three of the party have their eyes inflamed and Sweled in Such a manner as to render them extreamly painfull, particularly when exposed to the light, the eye ball is much inflaimed and the lid appears burnt with the Sun, the cause of this complaint of the eye I can't account for. from its sudden appearance I am willing to believe it may be owing to the reflection of the Sun on the water.

Clark also describes a case of snow blindness and a remarkable cure for it which, in reality, was the application of moist heat.

One Chief of the Mandans returned from Capt. Lewises Party nearly blind, this Complaint is as I am informed Common at this Season of the Year and caused by the reflection of the Sun on the ice and Snow, it is cured by jentilley swetting the part affected by throwing Snow on a hot Stone.

The formula of the eye water that made Clark famous among the Indians is given by Lewis in his report of conjunctivitis among members of his party.

Soar eyes continue also to be common to all of us in a greater or less degree. I use for soar eyes a solution of white vitriol (zinc sulphate) and the sugar of lead (lead acetate) in the proportion of 2 grs. of the former and one of the latter to each ounce of water.

Hygiene

To the modern hygienist health is far more than the mere attainment of physical perfection, the state of freedom from disease, or of being safe and sound. It is that true greatness only completely attainable when the individual makes the most of his physical, mental and moral capacities in his service to humanity. Both Lewis and Clark were healthy. By their accomplishments and by their expressions in their unguarded moments of reflection is revealed the quality of life that made them so fit to "live most and serve best."

Clark, in reply to the felicitations of the citizens of Fincastle and vicinity, radiates health.

It will be a pleasing reflection in future life to find that the expedition has been productive to those advantages of our Country, Geography and science that you are willing to imagine. To respect the rights of humanity has and ever will be the leading principle of my life and no reflection is more pleasing to me than that of effecting the object we had in view with the effusion of so small a portion of human blood.

Lewis was more temperamental than Clark. He exhibited a slight tendency to moodiness, but his attitude of mind was wholesome. Except for the unfortunate circumstances surrounding his death, history does not record that his mind dwelt more in the valley than on the heights.

This day (August 18, 1805) I completed my thirty first year, and conceived that I had in all human probability now existed about half the period which I am to remain in this Sublunary world. I reflected that I had as yet done but little, very little, indeed, to further the happiness of the human race or to advance the information of the succeeding generations.

I viewed with regret the many hours I have spent in indolence, and now how soarly feel the want of that information which those hours would have given me had they been judiciously expended, but since they are past and can not be recalled, I dash from me the gloomy thought, and resolve in future, to redouble my exertions and at least indeavor to promote those two primary objects of human existence by giving them the aid of that portion of talents which nature and fortune have bestoed on me; or in future to live for mankind, as I have heretofore lived for myself.

WHO WAS FREDERICK TAYLOR?[1]

By SELDEN SMYSER

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EVERY one knows Thomas Edison, knows that he is great and wherein his greatness lies. Most intelligent Americans also know Charles Steinmetz and that he too was great, but wherein his greatness lies is very uncertain with most persons; but Frederick Taylor! Who can place him?

Most people know nothing of him or merely that he was an "efficiency man." Others who are themselves men of large ability and scientific training believe him to have been one of the greatest thinkers of this century. Yet those who agree in believing in his greatness are far from agreeing with each other as to wherein his greatness lies. Others know him to have been an erratic individual who originated ingenious devices for speeding up men at work—methods that especially rewarded the superior and tended very subtly and effectively to break down the one bulwark of the workers—the union.

No other scientist of modern times has been honored by having his special work carried on by a voluntary organization of nine hundred able men united to continue his special work, as Taylor has been honored in the Taylor society. Probably no scientist since the days of witchcraft has been so condemned by having his scientific methods legislated against by a great nation. Yet for a number of years officers of the army or navy of the United States who might use Taylor methods of studying an industrial task in a government plant have been subject to a loss of pay under a law reenacted by congress, session after session.

The man who was the subject of such contradictory views and antagonistic activities has been dead for nearly ten years. Yet, until the appearance of Frank Copley's two volume biography, the material for a broad general view of his methods, accomplishments and fundamental aims has been difficult to attain. Taylor explained himself by activity rather than by words. His activity has so many different aspects and aroused so much and such varied emotions that Frederick Taylor was, and probably will continue for some years to be, a problem.

[1] "Frederick W. Taylor, Father of Scientific Management," by Frank Barclay Copley, 2 vols., 467–472 pp., Harper, $10.00.

Though it will not settle the controversy nor fix the position of Taylor in the development of modern thought and techniques the Copley volumes should do much to lead toward a more definite recognition and appreciation of the actual achievements of Frederick Taylor and much to lead toward a clearer understanding of the nature of his methods and of the philosophical implications of his attitude toward society. A work that has aroused such admiration, loyalty and faith as his must be evaluated. This biography, when taken along with the backward look which is our privilege to-day, should help to a recognition of those tactical blunders of Taylor in his attitude toward the unions which aroused the intense antagonism that so distorted the view of his work and aims. This is easy to see now in looking backward. The blunder was perfectly natural and excusable too, but it robbed Taylor of that reward to which his pioneer work entitled him—the reward of being widely understood and appreciated.

Mr. Copley is rather too apologetic and explanatory, it seems, in treating this matter. He labors too hard, "protests too much, methinks," in proving that Taylor really had the interests of the workers at heart. Taylor cared fully as much, far more, indeed in his later years for the interests of the workers than for those of the capitalists and owners. But far more than for either he cared for development of a new way of doing things in industry. He liked individual workers, but he cared for the workers as a class in much the same way that a New England abolitionist cared for the slaves. Taylor was a scientific genius driven by a great idea. This idea, from being vague, instinctive and antagonistic at first (at the time of his first clash with the lathe men in his effort to break up systematic soldiering), gradually became clearer and clearer as the years went by. The biography shows very plainly the development of this idea in and through Taylor's life and that is just the thing it should do.

The development of implications—philosophical, sociological, scientific and practical implications—of Taylor's work remains to be done and will probably be a gradual process covering several years, for the implications are far more radical, consistent and extensive than will be suspected by any who have not actually studied Taylor's work sympathetically. He himself lacked the power of explaining his methods in writing. He relied rather upon demonstration. He probably was incapable of formulating and systematizing the essential implications of his accomplishments. He thought in terms of actions rather than of abstract ideas.

Taylor was a true radical in his aims. Lenin was not more so. One would not have changed society more radically than the other.

But the method—there is the difference! They are as different as up and down. Both would have given us a social order believed to be shaped by science and pure intellect. Lenin attacked and changed the whole social order of his country according to doctrinaire principles. Taylor attacked the little details of industrial and social processes. He had very few doctrinaire principles in his creed, and these were principles of method only. Taylor believed that truth for the guidance of a man's conduct in reconstructing the social order is to be attained chiefly through life-size continuous experimentation conducted under normal industrial and social conditions but with all the accuracy of a research laboratory. Second: All traditional ways of doing things—the materials, tools, techniques and organization—however well established are to be suspected of being wrong and wasteful until they have been tested and verified by the experimental method as developed by modern science and adapted by the Taylor group. Lenin would begin by revolution and reconstruction of the social order itself. Taylor would begin the reconstruction of society by carefully investigating all the little details of social practice in industry, in government and commerce —by measuring, recording, calculating and discovering just where there is error and how great the error, and lastly how that error can be systematically eliminated from the practice of the shop and from the habits of the individual worker and from life.

No sociologist who believes in a positive method—a thoroughly objective method—has ever even proposed so clear a social program as Frederick Taylor demonstrated in large scale experiments—though he could not explain fully to men untrained in industry. He is the great successor of Compte and the precursor, perhaps, of a school of practical sociologists that is only beginning to be clearly conscious of itself.

Mr. Copley, a layman, has done better, it seems to the reviewer, than an engineer would have been likely to have done in writing a biography for the general reader. He has not in general shirked or treated vaguely the various technical matters involved in Taylor's career, but after careful study has made them clear to the lay reader. His admiration for his subject is great, but he is not undiscriminating. His careful, intelligent work, by which he has traced the development of Taylor's ideas, should start a period of more detached interpretation of the Taylorean program. For a new philosophical and social program is necessarily involved in Taylor's attitude and practice. It is one of extreme radical empiricism—of pragmatism raised above the level of philosophical discussion to the level of continuous cooperative large scale experimentation and reconstruction.

THE STATE OF SCIENCE IN 1924

THERMIONIC VALVES[1]

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Early Discoveries

The history and development of the thermionic valve is a striking example of the important industrial applications that sometimes follow from discoveries which take place in the course of purely scientific researches. In 1883 Edison sealed a metal plate into the ordinary electric incandescent lamp between the legs of its carbon filament. This plate was carried on a wire sealed through the wall of the glass bulb. He noticed that when the filament was made incandescent by a direct current sent through it, simultaneously a small electric current could be detected in a circuit between the *positive* terminal of the filament and the wire carrying the metal plates; on the other hand, no current could be detected between the *negative* end of the filament and the plate. This phenomenon was called the "Edison effect," but no explanation of it was given by its discoverer, nor was any practical use made of it at the time.

Investigations on the nature of the Edison effect undertaken by the writer in 1883 and onwards showed that the effect was connected with the projection in straight lines of particles from the filament; further, these projected particles carried a charge of negative electricity and could convey negative electricity from the filament to the plate, but not in the opposite direction. A further step in advance was made about 1897 by Sir Joseph Thomson, who showed that the chemical atoms of matter, which at the time were thought to be incapable of being divided, contained still smaller atoms of electricity, now called *electrons*. Soon afterwards, it was ascertained that the incandescent filament of the ordinary electric lamp is a prolific and continuous source of electrons, which are sent out in all directions.

About 1897 the application by Senatore Marconi of Hertzian electric waves for the purposes of wireless telegraphy began to create public interest. For detecting these waves he first used his im-

[1] Prepared for the Hand-book to the Exhibit of Pure Science arranged by the Royal Society for the British Empire Exhibition.

proved form of the coherer of Branly and Sir Oliver Lodge. It was, however, rather capricious and somewhat difficult to manage, and Marconi soon replaced it by his magnetic detector in 1901.

The Thermionic Valve

In Marconi's system of wireless telegraphy, the electric waves are generated by creating powerful vibratory currents of electricity in an aerial wire. The electric oscillations in this wire produce in surrounding space an electric wave which travels outwards with the speed of light, *viz.*, 186,000 miles per second. When these waves cut across another similar wire, a receiving aerial, they create in it feeble electric vibrations of the same type.

Now, if means could be found of converting the very rapid alternating movements of electricity in the receiving circuits into a uniform motion of electricity in one direction, it would then be possible to detect them, and therefore the electric waves, by the use of the telephone or galvanometer as in ordinary telegraphy, without the use of a coherer. The vibrations of electricity in wireless telegraph aerials are, however, very rapid, even up to a million per second, and none of the devices for "rectifying" or converting slow alternating electric currents into direct currents are of any use. The Edison effect, however, seemed to offer a solution of this difficulty, and in 1904 the writer found that if a metal cylinder was placed around the filament inside the vacuous bulb of an electric lamp carried on a wire sealed through the bulb, the appliance could "rectify" and therefore detect by the aid of a telephone or galvanometer these feeble high frequency oscillations. They can not directly affect a telephone because of their rapid reversals of directions, but the instrument above described acts as a *valve* when placed in the path of the oscillations and converts them into motions of electricity in one direction, in virtue of the fact that negative electrons are passing in the vacuous space only from the filament to the surrounding metal cylinder.

The apparatus was therefore termed an *oscillation valve*, and afterwards a *thermionic valve*. Later, in 1909, tungsten was used as the material for the filament in place of carbon, as it withstands a higher temperature and emits more electrons.

The above described two-electrode or hot and cold electrode thermionic valve was soon extensively adopted as a means of rectifying and detecting electric oscillations and detecting wireless waves.

In the spark system of wireless telegraphy then exclusively used, the waves come in little groups of 20 or 30 with longer intervals of

time between the groups. The Fleming valve rectifies the groups of oscillations produced in the receiving aerial into short gushes of electricity in one direction, and when these are passed through a telephone they give rise to a more or less musical sound which can be cut up by a key in the transmitter into the *dot* and *dash* or short and long sounds of the Morse code.

Developments of the Fleming Valve

In 1907 an addition was made to the Fleming oscillation valve by Dr. Lee de Forest, in the United States. Dr. de Forest introduced into a low vacuum valve a grid or zigzag of wire between the filament and the plate. This started a new line of development, and it was found that, if a cylinder of metal gauze or spiral of wire was introduced into the hard or high-vacuum Fleming valve between the cylinder and the filament, it enabled the device to act as an amplifier of oscillations, as well as a detector, so that very feeble high frequency oscillations could be magnified five or ten times by its aid. This suggestion was developed practically by the resources of the Western Electric and General Electric Companies, of America.

This modified form, then, became known as a *three-electrode valve,* and is sometimes called for shortness a *triode,* or other trade names. To employ it as an amplifier, a high-tension battery giving, say, 40 to 140 volts, is connected with its negative pole joined to the filament and its positive pole to the plate. A torrent of electrons is then forced from the filament, through the holes in the grid or gauze to the plate. If, however, a feeble electrification is given to the grid, positive or negative, it increases or decreases this electron current. The grid potential electrification can be obtained from any two points on a circuit in which a feeble high-frequency current flows, and the variation of the plate current of the valve will follow the variations of its grid potential. A number of such valves can be used in series and interconnected by suitable induction coils or transformers, and the plate current variations in one valve be made to create changes of grid potential in the next valve. By a series of such coupled amplifying valves, feeble electric oscillations can be magnified in any required proportion. It is the invention of this detector, comprising a series of amplifying valves, which has given us a detector of electric oscillations so enormously sensitive that has enabled us to signal half round the world.

The Thermionic Oscillation Generator

The thermionic valve, in its two- and three-electrode forms, possesses the power not only of rectifying and detecting electric

oscillations, but also of creating so-called continuous or undamped oscillations. This discovery at once rendered possible radio-telephony on a large practical scale, whereas it had previously only been an occasional feat of experts. The proper coupling through a transformer of the grid and plate circuits results in the production in these circuits of self-sustained oscillations by energy drawn from the plate circuit.

During and since the war, improvements have continually been made in the construction of large generating valves. Beginning originally with very small powers of a few watts in valves with bulbs like incandescent lamps, very large valves in glass bulbs, the size and shape of Rugby footballs, yielding an output of six or seven kilowatts, are now made. Valves of 10 to 20 kilowatts output or more have been made with bulbs of silica. The most recent advance in this direction has come to us from the United States. A method of making high power valves with bulbs partly of glass and partly of copper has been developed by the Western Electric Company, of America, based on the fact that a copper tube with a sharp edge can be welded to a glass tube. In large valves a source of trouble is the heating of the metal cylinder by the bombardment of the electrons. In the metal bulb valves the copper part forms also the anode cylinder, and it can be kept cool by immersion in water.

Large generating valves of 10 to 100 kilowatts have been made in this manner, and the General Electric Company, of America, are said to be preparing a thermionic generating valve of the two electrode or Fleming type with an output of 1,000 kilowatts or 1,300 horse-power. If this can be done, large thermionic valves will replace high frequency alternators entirely in long distance wireless stations. Already Marconi's Wireless Telegraph Company have a valve panel of 56 large glass valves in their Carnarvon Radio Station, with which communication is made direct to Australia. The present public wireless telephone broadcasting stations in Great Britain employ large valve generators in their transmission plant.

Modern Wireless Telephone and Telegraph Valve Receivers

The improvements made in the construction of the thermionic valve and the close study of its action imposed by the necessity for developing wireless telegraphy and telephony during the war have given us an extraordinarily sensitive and easily managed detector of electric waves, and the advent of wireless telephone broadcasting has created a novel trade in the manufacture of these valves for generating, amplifying and detecting electric waves.

In the receiving valve most commonly used, a straight filament of tungsten, or thoriated tungsten, or else platinum-iridium, coated with oxides of barium and strontium, is used. This is surrounded by a spiral wire forming the grid and by a nickel or molybdenum cylinder forming the plate. The ends of the filament, grid and plate are connected to pins on a cap, so that the valve can fit into a socket like an electric lamp.

In modern wireless telegraph receivers, one or more valves are used to amplify the oscillations; one to detect, and one or more to amplify the rectified currents.

Valves of this type were made to the number of three or four million during the war (1914–1918) and are manufactured now by the hundred thousand per annum for broadcasting purposes.

The Thermionic Telephone Repeater

An additional service the thermionic valve renders is as a perfect telephone relay or repeater. Telephone electric speech currents are enfeebled by flowing along a telephone wire, and for long distance working very thick and therefore costly wires were required. Thermionic amplifiers can, however, be inserted in the line to reenforce the currents.

By the use of these repeaters, telephonic speech is now transmitted right across the continent of America (4,000 miles), and they are now much used by the British post office. For shorter distances a great economy in copper can be obtained by their use. In short, the thermionic valve has effected a revolution in ordinary telephony just as it has made possible wireless telephony.

THE ORIGIN OF SPECTRA

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Spectra are of two kinds—band spectra and line spectra. Band spectra are very complex and originate in molecules. Line spectra are of varying degrees of complexity and have their origin in atoms. All compounds which can be excited to luminosity without decomposition give rise to band spectra, but the application of sufficient energy results in the appearance of the spectra of the component elements. Similarly, an element which gives a band spectrum in its molecular form will yield a line spectrum when the energy which excites it to luminosity is capable of dissociating the molecules into their constituent atoms. For example, the band spectrum of oxygen

or nitrogen may be produced by the passage through the gas of uncondensed discharges from an induction coil, and the line spectrum by the passage of the more intense condensed discharges.

Some of the earlier workers in spectroscopy were urged on by the idea that a spectrum must provide a clue to the structure of the atoms of molecules which produce it, and probably also to the mechanism of radiation. The majority of spectra, however, are exceedingly complex, and it was evident that the first step towards the elucidation of these problems was to discover the laws governing the distribution of the lines or bands, so that the essential features of a spectrum might be expressed in a simplified form. Theories of the origin of spectra, and of the constitution of atoms, are thus largely based upon investigations of regularities in the arrangement of spectral lines and bands.

In the discussion of such regularities, the position of a line is most usefully indicated by its "wave-number," or number of waves per centimeter. Thus, if λ be the wave-length in vacuo, expressed in Ångström units (1 Ångström unit $= 10^{-8}$ cm), the wave-number, denoted by ν, is given by $10^8/\lambda$. These wave-numbers are strictly proportional to the oscillation frequencies.

Line Spectrum of Hydrogen

The simplest of all line spectra is that of hydrogen. In the most familiar part of this spectrum, beginning with a line in the red, the lines follow each other with gradually diminishing intensities and at gradually diminishing distances from each other, so that they approach a definite limit in the near ultra-violet. Lines arranged in this manner constitute a "series," and it was discovered by Balmer in 1885 that the lines of the hydrogen series could be included in the simple formula

$$\lambda = 3646.14\, m^2/(m^2 - 4),$$

where m takes successive integer values ranging from 3 to infinity. In terms of wave-numbers, the formula becomes

$$\nu = 27419.6 - 109678.3/m^2.$$

There is another series of hydrogen lines in the extreme ultra-violet, called the Lyman series from the name of its discoverer, and others in the infra-red, each of which is generally similar in structure to the Balmer series. The entire spectrum is accurately represented by the simple formula—

$$\nu = N/\left(\frac{1}{m_1^2} - \frac{1}{m^2}\right)$$

where $m > m_1$ and $N = 109678.3$. This number was found by Rydberg to appear in the formulae for other spectra, and is called the Rydberg constant. In the formula for hydrogen, the Lyman series

is given by putting $m_1 = 1$, $m = 2, 3, 4 \ldots$; the Balmer series when $m_1 = 2$, $m = 3, 4, 5 \ldots$; and similarly for the other series in the infra-red.

Series in Line Spectra

Series which are of generally similar character to those of hydrogen were found by Rydberg and by Kayser and Runge to occur in the spectra of other elements. In the general case, several associated and overlapping series occur in the same spectrum, and are distinguished by the names principal, sharp, diffuse, fundamental and super-fundamental series. Each of such series may be represented approximately by Rydberg's formula

$$\nu = N\left[\frac{1}{(m_1+\mu_1)^2} - \frac{1}{(m+\mu)^2}\right]$$

where m_1 and m are integers, and μ_1, μ are constants special to each series. More exact representations of the series are given by including correcting terms in the denominators.

The formula representing a series thus consists of two parts, the first of which indicates the end or "limit" of the series, while the second is a variable part dependent upon a sequence of integers. The position of an actual spectral line consequently appears as the difference of two terms, one of which is the limit of the series to which it belongs. The word "term" has thus come to have a special meaning in spectroscopy; it signifies a wave-number which does not represent a spectral line in itself, but only when combined with another wave-number. The limit of a series is a term of one of the other series. The "combination principle" of Ritz expresses the fact that, with certain restrictions, terms from any one series may be combined with terms from other series to produce spectral lines.

Series, and their constituent terms, are now usually represented by abbreviated notations, of which the following are typical:

Principal series	$1s—mp$
Sharp series	$1p—ms$
Diffuse series	$1p—md$
Fundamental series	$2d—mf$

In each case the term on the left represents the limit of the series, and that on the right the sequence of variable parts corresponding to successive values of m. It should be further observed that series may consist of singlets, doublets or triplets. In a doublet system the p term has two values, and the d and f terms may also have two values. In a triplet system, the p, d and f terms have three values, and a singlet system is also associated with the triplets.

Elements of Group I in the Periodic Table of Elements, including the alkali metals, give doublet series, those of Group II triplets and those of Group III doublets. Among the elements of Group IV,

silicon at least includes triplets, and there is thus an alternation of doublets and triplets in harmony with odd and even valencies. Recent investigations have shown still greater complexities, in the terms relating to the later groups of elements, but even and odd multiplicities have been found to alternate throughout all the successive groups of the Periodic Table.

Origin of Spectra and the Quantum Theory

In view of the results of the analysis of spectra, it is clear that a successful theory must first account for the terms which give rise to the spectral lines by their combination. The terms have, in fact, a more immediate physical significance than the lines themselves. In the now well-known theory of Bohr, following Rutherford's conception of atomic structure, an atom is supposed to consist of a heavy positively charged nucleus, with a number of electrons circulating round it. In the normal state, the atom is neutral, and the number of external electrons is equal to the number of units of positive charge of the nucleus. When the atom is unexcited, the electrons may be regarded as traversing orbits more or less similar to those of planets or comets traveling around the sun, and obeying similar laws, with the difference that in the case of atoms the controlling forces are electrical.

The nature of the theory may be best indicated by reference to hydrogen, which has the simplest possible structure, each atom consisting of a positive nucleus of unit mass and unit positive charge and a single electron. When the atom is disturbed, the electron may temporarily traverse a larger orbit, but it is not free to occupy any orbit whatsoever, but only those in which the energy has definite values determined by the Quantum Theory. When the electron traverses one of these orbits, there is no radiation, and the atom is said to be in a "stationary" or non-radiating state. A spectrum line is produced when the electron returns to a smaller permissible orbit. Only one line is produced in a single transition, and the actual spectrum of many lines represents the integrated effect of a large number of transitions between the different permissible stationary states. The energy radiated during a transition is always a single quantum $\epsilon = h\nu$, where h is Planck's quantum of action and ν is the frequency of the radiation. The frequency of the emission, and therefore the position of the corresponding spectral lines, is thus dependent upon the difference of energies of the initial and final orbits. Exactly what happens during a transition is not yet understood. The "terms" of the spectra which have already been considered are accordingly proportional to the energies in the corresponding stationary states.

On this theory, Bohr has obtained a formula for the hydrogen spectrum which is identical with that derived from observations, within the limits of accuracy with which the quantum of action and the charge of the electron have been determined. The theory has also been extended, with remarkable success, to the explanation of the complex structure of the spectral lines, and of the effects of external magnetic fields.

Atoms of elements other than hydrogen are more complex in structure. A helium atom has a nucleus of mass 4 and positive charge 2 units, and two external electrons. The atom of lithium has three external electrons, and a nucleus with a treble positive charge, and so on throughout the table of the elements, the nuclear charge being equal to the "atomic number" of the element. The spectra, however, do not necessarily increase in complexity with increase of atomic number. In each case, the spectrum is considered to be produced by a single one of the external electrons, interacting with the rest of the atom, which, in the main, will have a single positive charge. Apart from a small effect due to the mass of the nucleus, the series constant for all elements is, accordingly, the same as that for hydrogen. Owing, however, to the presence of one or more electrons in the atomic residue, the possible stationary states are more numerous than in the case of hydrogen, so that several series occur in the same spectrum. The theory, however, is not sufficiently developed to permit the actual calculation of the positions of spectral lines other than those arising from a nucleus and a single external electron.

Arc and Spark Spectra

Spectra produced in the electric arc and the electric spark, though mostly showing some lines in common, usually exhibit important differences. Lines which are intensified, or only appear, in the spark are called "enhanced lines." Similar differences also occur in the spectra of gases as the energy which excites them to luminosity is increased.

The distinction between arc and spark spectra has become more definite in the light of Bohr's theory. Lines which occur in the arc, excluding those which are stronger in the spark, form series which are characterized by the Rydberg constant N, as already explained, and are attributed to neutral atoms. Enhanced lines, on the other hand, form series which involve the constant $4N$, and are attributed to ionized atoms; that is, to atoms which have lost an electron. The simplest example is afforded by ionized helium. When a helium atom has lost an electron, it resembles the hydrogen atom, except that the nucleus has a greater mass and has a double positive charge.

The spectrum is correspondingly similar to, but not identical with, that of hydrogen; it may be represented by the simple formula

$$\nu = 4N'\left(\frac{1}{m_1^2} - \frac{1}{m^2}\right)$$

where N' is slightly larger than N on account of the greater mass of the nucleus as compared with that of the hydrogen atom. This theoretical prediction agrees completely with the actual observations of the spectrum; the important line of ionized helium at λ4,686, for example, is the first member of the series given by putting $m_1 = 3$.

The spark spectra of elements other than helium show series which differ from those of arc spectra only in having a four-fold value of the series constant; they are also explained in a general way by an extension of the theory similar to that made in the case of arc spectra. It should be noted that in accordance with the so-called "displacement law," the spark spectrum of an element is of the same type as the arc spectrum of the element which precedes it in atomic number.

Spectra of Highly Ionized Atoms

Bohr's theory further indicates that atoms which have lost two electrons, or are doubly-ionized, may be expected to yield series which are characterized by the series constant $9N$. Trebly-ionized atoms would give series for which the constant would be $16N$, and so on. Series with $9N$ for the constant have, in fact, been established for aluminium by Paschen, whilst both $9N$ and $16N$ series have been traced by Fowler in silicon by the action of strong discharges through silicon fluoride. The chief lines of highly-ionized atoms are of necessity in the extreme ultra-violet, and can only be observed by the use of the vacuum spectrograph. The lines which appear within the ordinary range of observation belong to secondary series, but are, nevertheless, sometimes well-developed.

Important contributions to the theory of spectra have also been made by investigations of resonance and ionization potentials. In these experiments a gas or vapor is bombarded by electrons, the speed of which can be regulated by an adjustable electric field. Energy from an impacting electron is thus transferred to the atom, and is subsequently radiated on the return of the atom to its normal state. The energy required to develop certain spectral lines, or the complete spectrum, has thus been directly measured and has been found to be in agreement with that deduced from Bohr's theory.

The observational evidence is thus entirely consistent with Bohr's theory, and continued researches on spectra in the directions outlined may be expected to aid in the development of the theory, and in the deduction of the normal structure of the atoms of additional elements.

Band Spectra

The appearance of a band series is in several respects very different from that of a line series. The constituent lines are usually much more numerous and much closer together; further, although there is a certain resemblance to line series in the crowding together of the lines towards a "limit," series lines invariably fade out before the limit is reached, whilst band lines often reach the limit, and may even have their maximum of intensity in its neighborhood, so that the resulting "heads" are frequently very conspicuous features of the spectrum. Again, the law according to which the lines are arranged is quite different from that of the lines series, being of the form $\nu = A + Bm + Cm^2$, where A, B and C are constants and m is the number of the line in the series reckoned from any convenient starting point. The arrangement of the heads relative to one another may also be expressed by a formula of this type, which is the analytical representation of a parabola.

Experimental evidence has persistently related band spectra to molecules, but only in recent years has any detailed theoretical explanation been achieved. The quantum principles which have proved so strikingly successful in the elucidation of the problems of atomic radiation are no less applicable to molecules. But the case is considerably more complex, for in addition to the movements of the electrons within the molecule, we have to take into account the vibrations of the atomic nuclei and the rotation of the molecule as a whole. The total energy (W_1) associated with all these motions is characteristic of the particular state of the molecule at the moment, and if a change occurs in one or more of them the total energy will assume a new value (W_2). Then, exactly as for line spectra, we find that the frequency emitted (considering the case of a decrease of energy, *i.e.*, of radiation) is given by

$$\nu = \frac{W_1}{h} - \frac{W_2}{h}.$$

It is the greater variety of possible states of a molecule as compared with an atom which gives rise to the greater complexity of a band spectrum as compared with a line spectrum.

The present position is that, while the Quantum Theory has succeeded in accounting for all the main features of band structure, as, for example, the parabolic law mentioned above, there are many details as yet unexplained. Even the simplest bands hitherto studied, those due to helium, present problems of this kind, and in the case of the more massive and complex molecules, many difficulties present themselves. But it seems probable that these very discrepancies will, in the light of further study, provide the material for valuable extensions of our theoretical knowledge.

THE PREVENTION AND CURE OF RICKETS[1]

By WALLACE CRAIG and MORRIS BELKIN

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RICKETS, or rachitis, is one of the most important diseases of infancy and childhood. In the rachitic baby the bones fail to become calcified; consequently, they remain so soft that they are easily bent out of shape. The result, in many cases, is a deformity, such as knock-knee, bow leg, hunch back or lateral curvature of the spine.

Rickets is so common that most babies experience a mild degree of it at some period, especially in winter. If the baby is well cared for he will outgrow it completely. Rachitis is not in itself fatal. But, because it weakens the body, and because it becomes complicated with other diseases, it is an important cause of infant mortality. It is a disease of growth: the youngest children are the most liable to it; the prematurely born suffer most of all. Consequently, if the rachitic child survives to a mature age, when he ceases to grow, his active rickets disappears, but it may leave him permanently deformed or even dwarfed.

In order to understand these phenomena, one must know how bones grow. The embryonic bone is soft. It becomes hardened by calcification, that is, by deposit of mineral matter within the cells. The mineral matter contains a number of different salts in significantly constant proportion, including about 85 per cent. calcium phosphate. Thus it can be seen that calcium and phosphorus are the two elements peculiarly needed for the hardening of bones. Even after a bone has become calcified it is capable of increasing in size and changing in shape. One fact which enables it to do this is that while new lime salts are being deposited in the bone the old ones are being continually redissolved. Moreover, each bone serves as a storehouse from which lime may be withdrawn to supply other bones or to serve other uses—and lime has many other uses in the body besides bone-building. A considerable quantity of calcium and of phosphorus is absorbed daily from the food, and a considerable quantity is excreted daily in the urine and the feces. Thus there is a continuous metabolism of calcium and phosphorus.

[1] From the Laboratory of Biophysics of the Cancer Commission of Harvard University.

Rickets is a disorder of this metabolism. During active rickets, not only is there insufficient deposit of calcium phosphate in the bones, but in certain cases a bone which was once hard may actually become soft again, as the lime salts in it are dissolved away.

The body needs calcium and phosphorus not only for bone-building but also for a great many other functions. Each of these elements is a prime necessity of life. Each needs to be present in the blood in certain minimum amounts. And each needs to be present in a certain proportion or "balance" with relation to other elements. Disturbance of this balance upsets a great many different functions, among which we shall mention only one, *i.e.*, the action of the nervous system. Potassium and sodium (monovalent cations) increase the irritability of the nervous system; calcium ions decrease the irritability. Consequently, if calcium is deficient in the blood of a baby, the result is a certain hypersensitivity named "tetany," manifested in convulsions. Many babies who have rickets have convulsions also, both being due to calcium deficiency. A convulsion can usually be terminated by injection of a calcium salt into the veins. But this of course does not cure the disease. To cure the tetany or to cure the rickets the mineral metabolism must be brought back to normal.

Before speaking of the prevention and cure of rickets, we wish to speak of preliminary matters that will help toward an understanding of the problem. But for the sake of clearness it will be best to anticipate and to say at this point briefly that we now know two methods of treatment which prevent or cure rickets. One method is to supply a diet rich in vitamin D, a substance which has been found most abundantly in cod liver oil, but also in certain other fats and in green vegetables. The other method is to irradiate the body with ultra-violet rays.

Knowledge of these two preventives enables us to explain the very interesting facts in regard to the occurrence of rickets. The disease is found only in civilized communities, especially in large cities, where children are kept too much indoors, and are fed on a diet deficient in green vegetables and in other sources of vitamin D. In farming communities the disease is rare or unknown. Among savage peoples the children are, in general, free from it, because they are exposed to sunlight every day. The Eskimo baby is free from it, even though he lives in a dark hut, because he is suckled by a mother who consumes great quantities of animal fat and oil.

The seasonal occurrence also is explicable by its relation to vitamin D and to ultra-violet rays. For rickets is incurred mainly

in winter, when the baby receives too little sunlight and the mother receives too little green food.

The incidence of rickets among animals is similar to that among men: wild animals are free from it; domestic animals are subject to it. The disease of chickens known as "weak legs," which causes great losses to poultrymen, is either a form of rickets or something very similar to it. The symptoms are typical. At the age of three weeks the chick shows lack of vigor. At five weeks it has fully developed the "weak leg" condition: the toes are crooked, the nails long and curled; the legs are so weak that the chick can not stand up, it crawls to its food with feet and wings, using the wings as a pair of crutches. Its bill is soft, and its plumage ruffled. X-ray photographs reveal a lack of calcium salts in the bones. If the disease is allowed to reach this stage the chick usually dies.

Steenbock has shown that the disease of pigs which the farmers call "rheumatism," and which causes serious losses annually, is really rickets. Dogs, monkeys and rats also are known to suffer from rickets. The susceptibility of the rat is specially important, because rats are the most convenient animals on which to experiment, and a large number of experiments have been tried on them. Without these experiments, the knowledge which we now have of rickets and its cure would have been quite impossible.

The investigator of rickets has had to contend against great and peculiar difficulties. The difficulty of the subject is proved by the amount of research work that has been done on it. For three centuries such research has been continued. The original account of the disease was written by an English physician, Glisson, in 1650. From that day to this the number of investigators has increased at an accelerated rate, so that to-day a great many scientists are working simultaneously on various aspects of the problem. E. A. Park,[2] in a review of recent investigations upon "The etiology of rickets," cites 160 papers selected from the vast literature of the subject. There have been a dozen important theories as to the cause and cure of rickets. We shall mention only a few of them.

One theory was that there is a rachitic diathesis which is directly inherited. Statisticians tested this hypothesis, seeking out the family history of cases of rickets, and they did succeed in proving that the disease tends to run in families. But this is due to the fact that all members of a family are generally subject to the same living conditions, including matters of diet, sunlight and general hygiene. Experiments indicate that in a species of animal which is susceptible to rickets the disease can be produced in any in-

[2] E. A. Park, *Physiol. Reviews*, Vol. 3, p. 106, 1923.

dividual and it can be cured in any individual, under suitable experimental conditions. Consequently, if there is any difference between families, in susceptibility to rickets, it must be so slight as to be negligible.

While mentioning that so many theories have been held, it will be interesting to mention one that has not been held. No physician or scientist has supposed that rickets could be cured by drugs. A drug may be defined as a medicine which is not a food nor a natural constituent of the body. In looking through a considerable literature on rachitis, extending back into the nineteenth century, and some of it into the eighteenth century, we have found no mention of drugs. The literature mentions only sunlight, fresh air, exercise and other matters of hygiene; lime, phosphorus and various other items of diet, chiefly those that contain vitamin D; and certain endocrine glands, especially the parathyroid glands, which, of course, are natural constituents of the body. Physicians have recommended drugs for some of the complications of rickets, such as constipation; they have not thought that drugs could cure the rickets itself.

One theory was that rickets is caused by deficiency of calcium or of phosphorus in the diet. This was a very natural supposition, but, in practice, rickets is seldom, if ever, due to this cause. It is true, of course, that the disease can not be cured without an adequate supply of these two elements in the food, for without them calcium phosphate can not be deposited in the bones. This was known to our grandfathers, who gave their children milk and lime water and "sirup of hypophosphites." But our grandfathers were familiar also with the puzzling fact that even when lime and phosphorus are supplied abundantly in the food, yet calcium phosphate may fail to be deposited in the bones. They knew that rickets is due, not to any lack of lime and phosphorus in the food, but to the patient's incapacity for making use of these elements. In our day we call this a derangement of metabolism. But a complete explanation of it seems about as far away as ever. It is difficult to learn much about the chemical behavior of calcium and phosphorus in the interior of the body.

It is known that the endocrine or ductless glands are wonderful regulators of metabolism, and they probably exert an important influence on the metabolism of calcium. The different endocrine glands produce different effects, and the healthy functioning of the body depends upon the maintenance of a proper balance between the various glands. In particular, it is believed that the thyroid glands promote the elimination of calcium. Excessive

thyroid activity, as in exophthalmic goiter, results in an abnormally low amount of calcium in the blood, and this causes nervous irritability in the goiter patient, as it does in the child afflicted with tetany. But the parathyroids antagonize the action of the thyroids, causing calcium to be retained in the tissues.[3] Feeding parathyroid gland to the patient is beneficial in some cases of goiter and of tetany and of other disorders. It was thought at one time that rickets also could be prevented or cured by parathyroid therapy, but when this theory was tested in practice it was not a success. The endocrine glands are not the sole regulators of mineral metabolism, and it has been necessary to search for some other regulator which will prevent and cure rickets. This search has been rewarded by the discovery of two such regulators, one being vitamin D, and the other, ultra-violet radiation.

VITAMIN D

From a remote antiquity, among the fishermen of Norway, cod liver oil has been used both externally and internally as a cure for rheumatism. In 1771 it began to be used by English doctors for the same purpose. It was prescribed for rickets in the first part of the nineteenth century, at least as early as 1839. At first the physicians supposed that the oil simply supplied a fat that was more easily digested and absorbed than other fats. Yet even a hundred years ago they noticed that cod liver oil, taken by the spoonful, can produce in the patient an increase in weight which is out of all proportion to the small amount of oil that has been taken. This observation gave them an inkling of the fact that there is in the oil a growth-promoting factor, the factor which is now known as vitamin A. We need not review the history of the discovery of vitamins, because it has been reviewed already in this journal.[4] The remarkable peculiarity of vitamins is that they are present in the diet only in minute quantities, yet these minute quantities are vitally important. Due to this peculiarity, the vitamins escaped detection for a long time, and it is only within the last few years that scientists have distinguished different vitamins and have given to each a name and an epithet; as A, the growth-promoting, also called the antixerophthalmic; B, the antineuritic or antiberiberic; C, the antiscorbutic; D, the antirachitic. Vitamins A and D are both found in cod liver oil, but the discovery of D is very recent.

[3] H. W. C. Vines, "The Parathyroid Glands in Relation to Disease." London, 1924.

[4] B. W. Kunkel, "Calories and vitamines," SCI. MONTHLY, Vol. 17, p. 361, 1923.

Mellanby, of Cambridge, England, proved that there is an antirachitic factor, but he did not succeed in distinguishing it from vitamin A. In 1918 he published a preliminary report of his experiments on nearly 500 puppies. His method was: First, to discover experimentally a diet which was sure to produce rickets in any puppy; then to vary one constituent at a time and observe the effect. Each diet was fed to certain puppies for a long time —many months—in order to make sure whether it would produce rickets or not. Mellanby found that the antirachitic foods are in general those that contain vitamin A, cod liver oil being the most potent of them all. He was inclined to believe that vitamin A and the antirachitic factor are identical, but he was careful not to state this positively. Evidence against the supposed identity was found in the fact that butter-fat promotes growth and cures xerophthalmia but is of little use to prevent rickets. Of coconut oil the reverse is true: it can prevent rickets, but can not promote growth nor prevent xerophthalmia. After much study of the problem, E. A. Park and his associates at Johns Hopkins found that by oxidizing cod liver oil to a certain limited degree they could destroy the growth-promoting and antiophthalmic properties of the oil without destroying its antirachite value. That is to say, vitamin A was destroyed, while the antirachitic factor was left intact. The latter, then, is distinct from vitamin A, and it is now generally known as vitamin D.

Vitamin D has not yet been isolated; no man has ever seen it. But in 1924 Casimir Funk and two collaborators succeeded in getting from cod liver oil a concentrate which is only 0.0001 of the mass of the original oil, yet it contains all the vitamins, both A and D. This concentrate was tested in experiments on 300 rats, and proved to be preventive and curative of rickets. It was then given to the babies in a certain nursery in New York City, in 1-grain sugar tablets, each tablet being equivalent to a half teaspoonful of cod liver oil. Extracts of cod liver oil have been on the market for a great many years, but some of them are probably worthless.

It seems probable that vitamins A and D are both formed by green plants, for their own use, with the aid of the ultra-violet rays of sunlight. When the green leaves are eaten by an herbivorous animal, the vitamins pass from the digested leaves into the blood of the consumer. If the herbivorous animal is eaten by a carnivorous one, the vitamins are passed on into the blood of the latter. The sunlight that falls upon the vast area of the ocean is utilized by myriads of marine algae to form their vitamins. In

some of these algae, under the microscope, drops of oil can be seen. When the oil is extracted from a mass of the algae, it is found to have the characteristic odor of fish oil. This oil is probably the original source from which all the animals of the ocean derive—either at first hand or at second hand—their supply of vitamins A and D.

When an animal takes in more of vitamin D than is needed for immediate use, the surplus is stored. Vitamins A and D, both being fat-soluble, are stored in an oil in the liver. That explains why cod liver oil is so rich in these two vitamins. In birds, a good supply of the antirachitic factor is stored in the yolk of the egg, for consumption by the young bird before it hatches. Consequently, yolk of egg is a good preventive of rickets, and its use is recommended even for very young infants. A young mammal is supplied with vitamin D before birth from the mother's blood, and after birth from the mother's milk, and it stores part of this supply for future use. Thus the normal animal begins life with a good reserve store of vitamin D. This is one of the sources of difficulty in experiments; for when the experimenter puts an animal on a rickets-producing diet, the animal may show no effect for a long time, because it is utilizing its own reserve store of the antirachitic factor. Human milk is richer in vitamin D than cow's milk. Hence, breast-fed babies are less liable to rickets than those that are artificially fed. But the amount of vitamin D in the milk of any species depends largely on the amount of green food eaten before the milk is secreted.

Certain experiments[5] on rats indicate that vitamin D functions as a "regulator" of mineral metabolism. When rats are kept, without vitamin D and without ultra-violet radiation, on a diet containing very little calcium, the amount of calcium in their blood is found to be below normal. If now cod liver oil is added to the diet, even though the amount of calcium in the food is not increased, the percentage of calcium in the blood rises nearly or quite to normal. Under these conditions the organism manages to make very economical use of the small amount of calcium supplied to it. Experiments with low phosphorus give similar results. On the other hand, if calcium and phosphorus are supplied in excessive amounts, and cod liver oil is given, the concentration of these two elements in the blood does not rise above normal. Manifestly, there is some well-adjusted mechanism which "regulates" the mineral metabolism.

[5] B. Kramer and J. Howland, Johns Hopkins Hospital Bulletin, Vol. 33, p. 313, 1922.

Ultra-violet Rays

If an animal is given no vitamin D in its food, but the surface of its body is irradiated with ultra-violet rays, the result is that the concentration of calcium and of phosphorus in the blood is regulated, and rickets is thereby prevented or even cured. The irradiation thus produces the same effects as vitamin D.

It was not easy for the physician to guess that these two agencies, so apparently unlike in their nature, and utterly unlike in the mode of administration, could produce the same effect on metabolism. While the clinicians of the past century were experimenting with cod liver oil, the presence or absence of sunlight was affecting their results without their knowledge, and thus causing confusion. The difficulty was aggravated by the facts that the particular rays which are effective are invisible, and that they do not pass through glass. A child who was given a sun bath in a glazed "sun room" was not thereby protected from rickets; but the child who was taken into the open air on a sunny day was protected. Hence the physician very naturally, though erroneously, attributed the curative effect to the fresh air. Jacobi,[6] in an article on rachitis published in 1885, related that more than twenty years previously he had been in occasional attendance upon a certain baby suffering from rickets and convulsions. No treatment produced any benefit until, without the physicians' advice, the father took the baby into the street in the hardest winter weather. After the first long outing the baby was well of his convulsions, and "the physicians profited by their involuntary experience." Jacobi attributed the cure to the fresh air, and the fresh air theory was held for a long time afterwards.

But while Dr. Jacobi was writing a summary of his observations in America, an English physician, Dr. Palm, was practicing in Japan, and he noticed in that country the absence of rickets among the children of the poor. This observation led him to make a study of the geographic distribution of rickets. He gathered a great mass of data from three continents, and from these data he drew the conclusion that the important factor in the distribution of rickets is not fresh air but sunlight. About thirty years later the fact that sunlight cures rickets was proved experimentally by Hess and Unger, of Columbia University.

In 1904 an attempt was made in Germany to cure rickets by means of electric light, but the attempt was not very successful, because the bulbs used were of glass, and the glass prevented the

[6] A. Jacobi, "Rachitis." Reprinted in Collectanea Jacobi, Vol. 3, Contributions to pediatrics. New York, 1909 (see p. 182).

emission of the ultra-violet rays. In 1919, in a home for rachitic children in Berlin, Dr. Huldschinsky cured some of the inmates in two months by irradiating them with a quartz mercury-vapor lamp, which emits ultra-violet rays in abundance. The quartz lamp is now coming into general use, as a means of curing rickets.

Ultra-violet rays have been proved to be of great practical importance in curing "weak leg" in growing chickens, a disease which, as was explained above, is similar to rickets. Ultra-violet rays were first used on chickens by J. S. Hughes at the Kansas Agricultural College. An extensive experiment has just been conducted in the Harvard Biophysics Laboratory under the direction of Dr. W. T. Bovie, and at the University of Maine under Dr. C. C. Little. A rickets-producing diet was fed to 225 chickens. It was found that the rickets can be prevented or cured by three different treatments. The first consists in mixing cod liver oil with the food. But the oil is evidently distasteful to the chickens; it causes them to eat less and to gain less weight; therefore it is not a practicable method for the poultryman. The second method is to give the chicks constant access to an outdoor run, where they enjoy the sunlight. But this is not always practicable in our northern states, where the spring weather is far too severe for little chicks. The third method is to expose the chicks 15 minutes daily to the rays from a quartz lamp. This method is probably a practicable one for the poultryman, at least as a supplement to natural sunlight.

Experiments on animals have been emphasized throughout our discussion, because they yield such definite results. The investigator can subject an animal completely to the conditions called for by the experiment. He can not do this with a baby. It would not be ethical to produce rickets deliberately in a baby for experimental purposes. In so far as this is true, our knowledge of the disease in babies must always remain less precise and less certain than our knowledge of it in animals. But immediately after the great war, Dr. Harriette Chick, of England, saw an opportunity to try some fairly definite experiments on babies. There were many babies in Vienna who were being fed on a rickets-producing diet, because they were under the care of a physician who had more faith in calories than in vitamins. Miss Chick secured permission to take some of those babies under her charge. She went to Vienna with a staff of physicians and assistants and with the necessary supplies. She proved that rickets can be cured in the human species, as it can in the rat and in the fowl, by cod liver oil or by exposure to sunlight or to the rays of a quartz lamp. In so doing,

she not only verified a theory, but also improved the health and probably saved the lives of some of the babies.

No one has yet determined precisely which rays are effective in curing rickets, but it is known that they are of wave length[7] shorter than 313 mμ, and perhaps even shorter than 302 mμ. Such radiation is entirely beyond the range of our vision. It can not pass through glass, and therefore can not enter our houses except when the windows are open. Perhaps at some time in the future children's nurseries will be fitted with quartz window panes, which will allow the ultra-violet of the sunlight to enter. That will be a boon especially to prematurely born infants, who can not be taken out of doors. Ultra-violet radiation is absorbed to some degree by pure air, and much more by air laden with dust and moisture. Consequently, in the streets of a dark, smoky city there is very little of it. At sea level in bright, sunny weather there is enough of it to cure rickets if the patient is out in the sun for some hours each day. In high mountains there is more of this radiation; but even the mountain sunlight has passed through a hundred miles of air and has lost most of its ultra-violet rays during the passage. The light of a quartz mercury-vapor lamp is far richer than mountain sunlight, in ultra-violet; it is so rich that, as was mentioned in connection with the experiment on chickens, rickets can be cured by exposure to the quartz light for 15 minutes a day.

In this article we have aimed to give a summary of empirical facts regarding the prevention and cure of rickets, especially by vitamin D and by ultra-violet rays. We have not discussed the problem of explaining how these two agencies influence mineral metabolism and how they cure rickets. That problem will be treated by Dr. Bovie in a subsequent article.

[7] The millimicron, mμ, is 0.000001 mm, or about $\frac{1}{25{,}000{,}000}$ inch.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

NEW FASHIONS IN LOCOMOTIVES

ONE curious thing is observable alike in the evolution of inventions and the evolution of plants and animals. They will run along about the same for many years or centuries, getting bigger perhaps but retaining essentially the original structure, and looking much alike; and then all of a sudden new varieties will appear, many different kinds, and the primary form, forced to meet these new competitors, is either crowded out or undergoes a rapid development. The biologists call this multiplication of novel forms and freaks a "mutation" period.

The railroad locomotive is now in the midst of such a mutation period. For the past hundred years it has stuck strangely close to its original type. In looking over the models of locomotives in the National Museum last week I was struck with the monotony of the exhibits. The "John Bull" that was built by George Stephen in 1831 for the Camden and Amboy R. R. looks about as much like the giant locomotive of to-day as a colt looks like a horse. It employed the same power and consisted essentially of the same parts: coal tender, furnace, boiler, piston engine, big wheels behind, little wheels in front, smokestack, headlight, cowcatcher and bell, all the familiar things arranged in the familiar order.

But now we are beginning to see various new varieties of locomotives; some without coal, some without pistons, some without steam, some without fuel of any kind. The electric locomotives fed with power through a third rail or trolley wire look more like the old steam engines than they need to, probably for fear of disconcerting the engineers and shocking the public. It is a wonder the makers do not think it necessary to stick on a fictitious smokestack with a pennant of black gauze streaming out of the top to satisfy our sense of the fitness of things.

In Europe steam turbines are being used in place of the old reciprocating engine. Leon Metais, a French engineer, has invented a locomotive in which the steam is first used in a high pressure turbine and from this passed on to a low pressure turbine. These run a dynamo which sends its current to eight motors, one on each axle. It is claimed that such an engine will run longer and get more than four times the power out of a given amount of fuel.

The Diesel engine, which does not employ coal or steam but gets its power from the explosive combustion of petroleum under high pressure, is still more efficient and economical. In Sweden the Atlas Company, of Stockholm, makes a locomotive with a Polar Diesel engine of the four cycle sort with twelve cylinders.

The Soviet government has had constructed at the Esslingen works in Germany a Diesel electric locomotive which claims an efficiency of 21 to 27.4 per cent. at a load of 440 to 1,060 horse-power, and a reduction of two thirds in the fuel consumption.

WILLIAM JAMES BEAL

In his botanical garden at Amherst, Mass., at the age of eighty-seven years. Dr. Beal was a pioneer in botany and professor at the Michigan Agricultural College for fifty years. The engraving is taken from the memorial prepared by Mr. and Mrs. Ray Stannard Baker, after the death of Professor Beal at the age of ninety-one years.

In America also efforts are being made to break away from the steam engine by using some form of the Diesel engine with electric drive and control. The General Electric Company has built a trial locomotive of this sort which is now being loaned out to various railroads willing to give it a trial in their switching yards. Its 300 horse-power engine is directly connected with a direct current generator of 200 kilowatts. The 60-ton locomotive carries with it enough fuel for 48 hours of continuous switching service. It consumes only .43 pounds of fuel oil per brake horse-power hour.

The Baldwin Locomotive Works expects to be running trains this summer with its new type of Diesel-electric locomotive which it has perfected after ten years of experimentation on the problem of construction. This is said to save between 25 and 50 per cent. in the cost of fuel over the steam engine. It uses a twelve cylinder two-cycle Diesel of more than a thousand horse-power.

If the steam engine is to meet such competition it must reform its ways and curtail its extravagance, and it is beginning to do so. The American Locomotive Works has built for the Delaware & Hudson Company R. R. a 273-ton engine that brings steam to a pressure of 350 pounds instead of the customary 200, and is said to be capable of developing a third more power with the consumption of a third less fuel and water. The new locomotive is appropriately named the "Horatio Allen" after the engineer who imported and ran for this company in 1829 the "Stourbridge Lion," the first locomotive to be set to work in America.

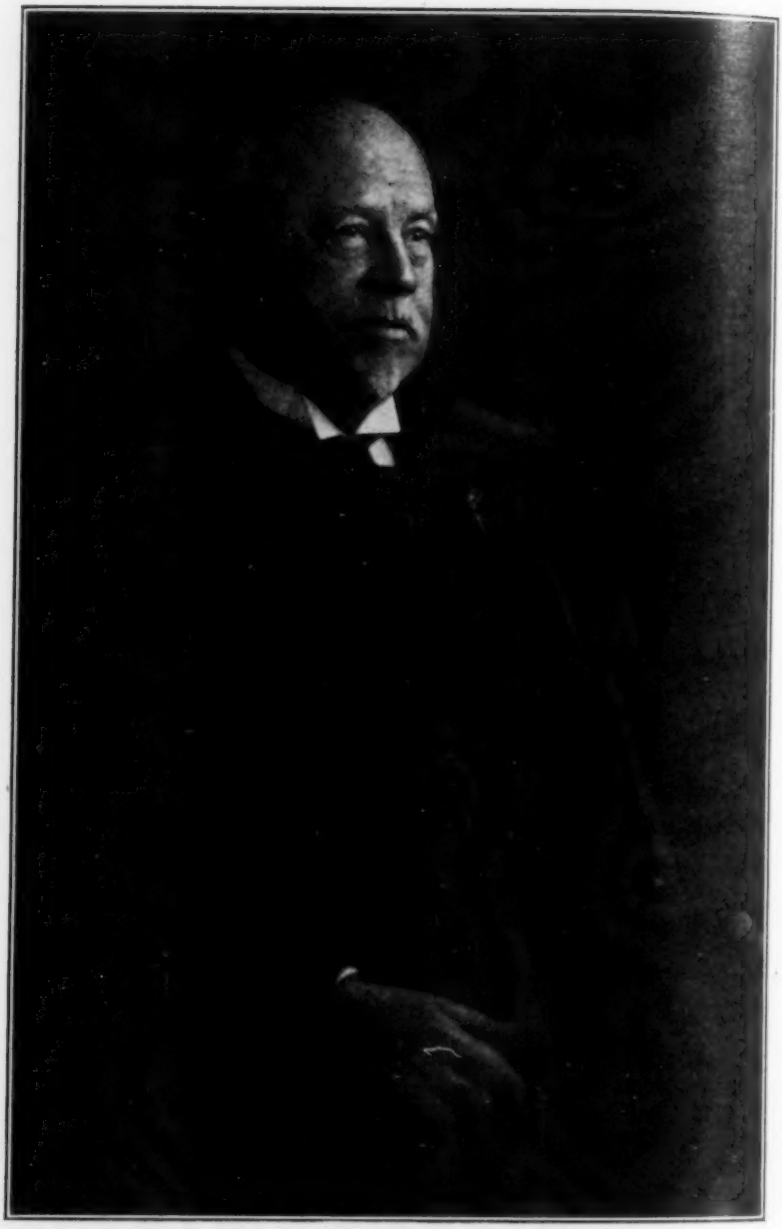
The old steam engine has lost its monopoly and it remains to be seen whether it will be crowded completely off the tracks or be content with a humbler position.

TWELVE YEARS' HUNT FOR A GERM-KILLER

Readers of the item appearing recently in the papers, that a new disinfectant had been discovered fifty times as strong as carbolic acid, had no way of knowing what lay behind it—or before it.

In the first place the word "discovered" is misleading. This conveys the impression of a lucky strike, like the diamond that a child in South Africa picked up as a pretty pebble or the nugget of gold that a sheep herder stumbled upon in Australia. Such is a true discovery, the accidental finding of something already existing. But this new germicide is not, properly speaking, a discovery; it is an invention, as much an invention as a new radio apparatus. It is not a natural product, suddenly found to be of value, like quinine in Peruvian bark. It is the successful culmination of a long, arduous and systematic study of how to construct a molecule that would serve a particular purpose; this particular purpose being to produce a chemical that would distinguish in the dark between the friends and foes of the human body, that would pass through the blood stream, killing all the disease germs it met and not injuring the body cells which are so much like them in size, shape and composition that the microscopist has difficulty in telling them apart.

The beginning of this research, the germ of the germicide, is to be found in a paper that Professor Treat B. Johnson, of Yale University, published in the *Journal* of the American Chemical Society in 1913. And he has stuck to it ever since until now, a dozen years after, his work is publicly recognized as one of the triumphs of modern medicine. The



—From the Book of Portraits of the Faculty of the Medical Department of the Johns Hopkins University, by Doris Ulmann

WILLIAM H. WELCH

Director of the School of Hygiene and Public Health, The Johns Hopkins University, distinguished for his contributions to pathology and medical education, who celebrated his seventy-fifth birthday on April 8.

"Yale Bulldog" spirit gains victories in other fields than football, although the papers do not make so much fuss over them.

The material for the new disinfectant comes from that same big black grab-bag from which the chemist has drawn so many useful dyes and drugs, the coal-tar barrel. One of these products, phenol or carbolic acid, is a valuable antiseptic, strong but clumsy, careless in discriminating between the invading microbes and the home guard. It sears the flesh like a hot iron when applied in full strength.

A near relative to phenol is resorcinol, a milder substance which some of us have used in the vain attempt to make two hairs grow on a head where none would grow before. Now both these compounds consist essentially of a ring of six carbon atoms, and what Professor Johnson discovered was a new way of attaching a chain of carbon atoms to this ring. This enabled him to make a series of similar compounds with side chains composed of from one to any number of carbon links, and it was found that the power to destroy germs increased as the chain was lengthened until there were six carbon atoms in the chain, but fell off thereafter. So the most powerful germicide of this series is the sixth which is accordingly called "hexyl-resorcinol," though doubtless a name with less than six syllables will be selected for it before it is put on the market, otherwise people would be reluctant to call for it at the drug store.

Professor Veader Leonard, of Johns Hopkins University, who has been testing the antiseptic power of these compounds, finds this compound is about fifty times as effective as our old carbolic acid. That is to say, it could be diluted with fifty times as much water and would still be as poisonous to the microbes without injuring the bodily tissues. It can be safely taken internally by the mouth, and since it passes out largely through the kidneys it may be used to destroy the microbes and parasites of a tract of the body that has been hitherto difficult of access.

The member of the family with four carbon atoms in the side chain, known as "butyl-resorcinol," is about half as powerful, but may prove quite as useful for such purposes as gargles, tooth-paste and the treatment of skin wounds, for it is stable and has no disagreeable odor.

All these compounds and many others are being systematically prepared and their physiological effects investigated by a committee of the National Research Council. Such team work is likely to bring about much better results, quicker and more reliable than the haphazard efforts of isolated individuals. The ideal germicide is yet to be found, and it is quite possible that in time something may be found, or rather made, to take the place of such metallic poisons as mercury and arsenic, which do kill the parasites of the body but not without danger to their host. We also have reason to hope that the chemist may make something that will hunt out and destroy the bacillus of tuberculosis in its most secret lairs.

A PAINLESS WAY OF PAYING WAR DEBTS

WHEN a man finds himself overwhelmingly in debt and unable even to pay the interest, he naturally thinks of realizing on his real estate, especially if he owns more land than he can work. Why should not a nation do the same?

France, for instance. France is land poor. The country taken altogether is larger than the United States, fifty-four per cent. larger. France has extensive territories in Africa, Asia, America and Oceania which she

—From a photograph by Julian Scott

DR. W. J. V. OSTERHOUT

Professor of botany in Harvard University, who will become a member of the Rockefeller Institute for Medical Research.

has neither the men nor the money to develop. She has debts that she is too poor to pay.

Among her chief creditors is the United States and among her scattered parcels of property is one which is valueless to her but would be of great value to us, that is, French Guiana. This is about the size of Maine, mostly virgin territory, and largely unpopulated. Only about one twenty fifth of one per cent. of the area is under cultivation. It is rich in natural resources, mineral and agricultural, yet the French make no use of it except as a penal colony and are likely to abandon that. Few Frenchmen live there except the convicts and their keepers, so there would be no violation of local patriotic sentiment in its transfer to a foreign flag. If we should accept this territory in lieu of all France owes us we should be paying $156 an acre for it, an absurdly extravagant price, yet we could afford to make a very considerable reduction in our bill against France, for it would be better to have something tangible rather than rely upon promises already partially repudiated.

Great Britain alone among our debtors is paying up, yet she finds the burden of taxation almost intolerable and should be glad to be relieved of part of it by the cession to us of British Guiana. This is larger and richer than the French, yet is unprofitable to the mother country. It is larger than Utah, but less than two per cent. of it is occupied and less than a quarter of one per cent. is under cultivation. Only four per cent. of the scanty population is of European origin. We could not afford to cancel all that England owes us in exchange for British Guiana, for that would figure up about $70 per acre, yet we paid Denmark $500 an acre for the Virgin Islands.

That France and England could get relief from their heavy obligations by selling to the United States their surplus territory in and about the Caribbean Sea has been suggested by Professor Charles Gide, of the Paris Law Faculty, and by Lord Rothermere, brother of Lord Northcliffe. We should hesitate to take at any price the West India islands, for they have scant area and dense population, but the Guianas are the opposite and rather resemble the North American continent when we took possession of it. Under American administration and by means of American machinery the Guianas could be made a source of supply for petroleum, sugar, rice, rubber, beef, hides, lumber, hemp, cocoanut oil, cocoa, fruits and alcohol for motor fuel. This is almost the only undeveloped territory area of all the immense area lying between the Orinoco and the Amazon. Tropical real estate is bound to rise in the future on account of recent scientific discoveries and no country can afford to be without it. In a recent discussion of the problem of British Guiana at the Royal Society Professor L. Knowles said: "I have little doubt that the nation which controls the tropics will in the twentieth century control the most important raw materials and the growing markets of the world." France and England might well let us have this small fraction of the 2,300,000 square miles that they gained in the war which we aided them to win.

ELECTRIFYING THE SKIN

WHEN sunlight strikes the bare skin it knocks out an electron from one of the atoms on the surface. This discovery was announced before the French Academy of Sciences on March 2 by Jean Saidman.

He stood a man on a stool insulated from the ground by legs of glass or rubber and gave him a certain charge of negative electricity, which of

course is altogether imperceptible to the person experimented upon. The electricity leaked away gradually and in 250 seconds three quarters of it had disappeared. Then he turned a ray of ultra-violet light from a mercury lamp twenty inches distant upon a section of the exposed skin less than two inches square and found that the electricity leaked away four times as fast. Three fourths of the original negative charge was gone in 64 seconds instead of 250. When a larger area of the skin was irradiated the loss of electricity was more rapid. Sunshine produced the same effect, though more slowly because the light of the sun is not rich in the energetic rays beyond the violet end of the spectrum. The leakage of electricity continues for some seconds after the light is shut off, probably being carried away by ionized particles of air and dust.

It has been known for some years that when a metallic surface, such as a polished plate of silver or copper or a fresh cut face of sodium or potassium, is exposed to ultra-violet rays it loses negative electricity. This is due to the detachment of the corpuscles of negative electricity, known as "electrons," which revolve in the outer orbits of an atom about the central and positive nucleus. This action of light on electricity is called the "photo-electric effect." It is this photo-electric effect that causes the photographic plate to record the image which the light casts upon it. It is this that activates the green leaf to store up food by aid of energy of the sun's rays.

The human skin is found to be one third as sensitive to the photo-electric effect as a sheet of copper, and we may find in this an explanation of the mystery of the curative effects of sunshine on the skin. The ultra-violet rays have a wave-length too short to be perceived as light by the eye, and they are unable to penetrate the clothing or the skin because they are so easily absorbed. Even a microbe, so small as to be barely visible in a microscope, is too thick for these short waves to pass through. So if one microbe is lying on top of another when exposed to these rays the top one will be killed by them, while the lower one, being sheltered by the body of his mate, will escape injury.

Yet the ultra-violet rays of bright sunlight, or the stronger rays produced by the mercury quartz lamp, not only tan or burn the skin but have a profound effect upon the deeper tissues, changing the composition of the blood, stimulating it to greater activity against disease germs and often curing sores and bone diseases. This is to say, these short and easily deterred waves which can act only on the outer surface of the skin produce more profound effects upon the whole system than the longer waves of red light and heat which readily penetrate the skin and even pass through the entire body. M. Saidman suggests that the influence of the ultra-violet rays is exerted through the photo-electric effect on the surface which is transmitted from layer to layer into the interior of the body.

The use of violet and ultra-violet and radium rays in this country is becoming a fad that seems likely to rival the famous blue-glass craze of the seventies. All sorts of ray apparatus and preparations are now finding a ready sale for the cure of all manner of ailments, but it may be said of most of them that they are either too weak to be of any use whatever or too strong to be used indiscriminately and unintelligently. It requires a specialist and expert to employ powerful rays of this kind, for they may produce very serious effects at the time or much later. Those who want to experiment for themselves in this fascinating field of radio-

therapy should stick to the oldest source of such rays, the sun. It will be cheaper for them and they will run a risk of nothing worse than a sunburn.

HOW TO LOSE WEIGHT

I HAVE learned how to lose weight without dieting, exercising, drugging or massaging. I have long been interested in this question, not only from scientific curiosity, but for personal reasons which it is not necessary to mention. Knowing that many others are interested for the same unspecified reasons, I hasten to give the information freely to the world.

I have not tried the process yet but I will not wait for that. If people with a new panacea for bodily or political ills delayed recommending it to others till they had tried it out the world would lose much literature. Besides I get the information from the weightiest authority on weight in the country, namely, the U. S. Coast and Geodetic Survey, which makes gravity determinations at over 300 stations with the utmost accuracy. The survey does not apply the results of its investigations to the personal problem. The credit for this is wholly mine. But from the survey figures I extract the following secret:

The way to lose weight is to travel.

But it all depends upon the way you travel.

You must go from high latitudes to low latitudes or from low land to high land, or better, do both.

For instance, if you weigh two hundred pounds—I don't mean to insinuate that you do, but some people do, and it makes the figuring easier to start with—if you weigh two hundred pounds at the North Pole—of course you don't, but call it so for convenience—and you journey to the mouth of the Amazon, you would weigh only about 199 pounds there, and this is not considering possible losses on the voyage. This may not seem to everybody a considerable reduction, but if you weigh two hundred pounds you will know that it is well worth working for. Every merchant knows that marking down an article from $2.00 to $1.99 makes it much more attractive to bargain hunters.

If you travel from the North Pole to the top of Mount Chimborazo, Ecuador, which is near the equator and four miles high, you would reduce your weight from 200 pounds to 198.6. Of course, in order to gain this loss you would have to be weighed by spring balances and in a vacuum, for if beam balances were used the weight of the weights would fall off in the same proportion as you did and if you were weighed in air its buoyancy at low levels would tend to counteract the effect.

Or, if you are not interested in your personal avoirdupois, you could make money by buying gold on Mount Chimborazo and selling it at the North Pole. A nugget of gold weighing 200 ounces Troy on the mountain would increase in weight by about 1.4 ounces on being transported to the Pole and would be worth about $28 more. But perhaps it would be more profitable to travel about Europe and take advantage of the exchanges.

The reason for such variations of weight is due to the fact that a rotating body develops a centrifugal force that tends to throw off any loose object on its rim. We have all been struck by this while standing near an automobile speeding by in the mud.

Since the earth is a rotating body it, too, develops a centrifugal force which would be sufficient not only to throw off all unattached objects on

the surface but to tear the earth to pieces, like a giant defective fly-wheel, if it were not overbalanced by the centripetal pull of gravitation.

The pull of gravity, as we ordinarily understand it, is a combination of two pulls or forces, the gravitative force of the earth and its centrifugal force. Both of these forces vary for different places on the earth. The centrifugal force varies from a maximum at the equator to zero at the poles, due to the fact that the linear speed of rotation is greatest at the equator and nothing at the poles. The other force, gravitation, depends upon the distance to the center of the earth and is, therefore, greatest at the poles, since the distance to the center is there 13 miles shorter than from a point on the equator. For the same reason gravitation is less at sea level than at the top of a high mountain peak in the same latitude.

There are other causes for the variation of gravity on the surface of the earth. For instance, gravity is less on a plateau than at the top of a sharp mountain peak of the same elevation, and is less above rock of low density than above heavy rock. It is possible that the discovery of material of abnormal density by gravity observations may have some bearing on the search for mineral or oil deposits hidden deep in the earth.